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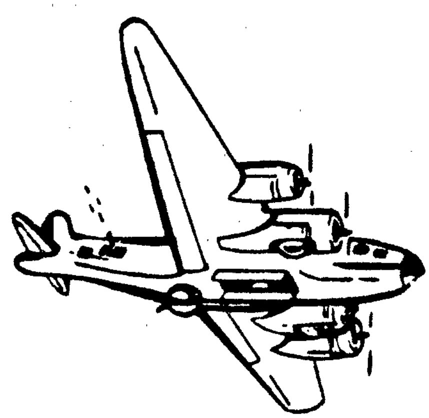

MEMORANDUM
REPORT No. 593

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An Effectiveness Study of the Infantry Rifle

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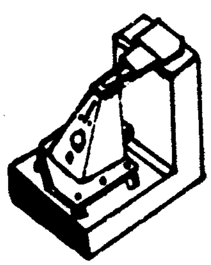

DONALD L. HALL

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BALLISTIC RESEARCH LABORATORIES

MEMORANDUM REPORT NO. 593

March 1952

AN EFFECTIVENESS STUDY OF THE INFANTRY RIFLE

Donald L. Hall

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BALLISTIC RESEARCH LABORATORIES

MEMORANDUM REPORT NO. 593

DLHall/bts
Aberdeen Proving Ground, Md.
March 1952

AN EFFECTIVENESS STUDY OF THE INFANTRY RIFLE

ABSTRACT

A study of the probability of hitting and of wounding for a family of rifles is made. The rifles are compared on the basis of the single shot probability and the expected number of kills for a given total weight of rifle and ammunition.

Some experimental data on a commercial cal. .220 rifle are included.

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INTRODUCTION

In accordance with the request of Office, Chief of Ordnance in their letter /OO 474/18 (s) dated 28 Nov 50, a study has been made of the effectiveness of an infantry rifle. This report was prepared without regard to present established military characteristics of the Army Field Forces, since the purpose of research is to provide basic data which may assist Army Field Forces in developing future requirements. The status of critical raw materials was not considered. The conclusions contained herein are tentative and are subject to experimental confirmation.

In evaluating such a weapon, it is necessary to consider its probability of hitting when in the hands of a combat soldier, its ability to wound, and the weight of rifle and ammunition. These characteristics are somewhat dependent on each other. The probability of hitting of a rifle is primarily dependent on the range and muzzle velocity, or more explicitly on the flatness of the trajectory. The wounding power is a function of mass, striking velocity, and bullet shape. Both the hit probability and the wounding ability could be improved by increasing the muzzle energy, but this would increase the weight of both the gun and the ammunition thus decreasing the number of rounds that the soldier could carry.

In this study a family of weapons was considered. The caliber was varied from .30 to .21 and the weight of the charge was taken to be 1.0, 0.8, and 0.6 times the charge (53 grains) normally used in the present standard Ball M-2 Cal. .30 ammunition.

METHOD

All bullets were considered to be homologous to the Cal. .30 Ball M-2 ammunition. Muzzle velocities for the various calibers and charge weights were extracted from an unpublished report prepared for Mr. R. H. Kent* of BRL. These data are summarized in Table I.

In determining the number of rounds of ammunition to be attributed to each gun, it was assumed that the weight of the cartridge case was directly proportional to the weight of the charge. Knowing the weight of the bullet, it was possible to determine the weight of the complete round. The M-1 rifle with 96 rounds** of Cal. .30 Ball M-2 ammunition was taken as a standard. The weight of gun plus ammunition is approximately 15 lbs.

Since the receiver and chamber sizes are directly proportional to the cartridge length, and since a reduction in caliber and charge would reduce the cartridge length, a reduction in receiver and chamber sizes can be computed and the reduction in rifle weight determined. Because

* By Mr. H. P. Hitchcock and Mr. James Prevas.

** This ammunition load was recommended by Col. S. L. A. Marshall in his book, "The Soldier's Load and the Mobility of a Nation".

this has disregarded all other factors which might contribute to the reduction of rifle weight, it is felt that this tends to underestimate any reduction in rifle weight from smaller rounds and to favor the heavier charge and larger caliber. Table II shows the expected reduction in rifle weight and the ammunition weight. Table II also shows the total number of rounds the soldier can carry without exceeding a total weight of 15 lbs. and the reduction in the soldier's load if he were limited to only 96 rounds for all rifles.

To determine the hit probability the following assumptions, felt to be reasonable, were made:

(1) A standard deviation of range estimation of 20% of the range to the target.

(2) A standard deviation of cross wind estimation of 3 miles per hour.

(3) A standard deviation of aiming and ballistic error of 0.6 mils for all ranges.

(4) A target 3-1/2 ft. high and 1 ft. wide.

Ballistic data for all computations were taken from Siacci tables.* Since the bullets were all taken to be homologous to the Cal. .30 Ball M-2, the same form factor was used.

The hit probability was calculated** for ranges of 200 to 1000 yards and is plotted in Figures 1, 2, and 3.

So as to get a better overall picture as to the result of changing caliber and charge weight, the ratio of the probability of a hit for a given gun to that for the M-1 caliber .30 rifle has been computed and is plotted in Figure 4. As may be expected, the higher the muzzle velocity, the greater the expected hit probability.

To obtain the probability that a target when hit would be severely wounded or incapacitated, wound ballistic data were used both from Dr. Sterne's Technical Note No. 556 and from estimates of Dr. F. A. Odell of the Biophysics Branch, Medical Laboratory, Army Chemical Center.

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* Appreciation is expressed for the help received from Mr. H. P. Hitchcock through his advice on the computation of trajectories and determination of form factors.

** The author is indebted to Mr. W. C. Benjamin for all the calculations and graphs appearing in this report.

For Dr. Odell's estimates the following assumptions were arbitrarily ma:

(1) That the target was standing, facing the gun with a uniform probability density of possible impact points. (All points of impact equally likely on the target.)

(2) The soldier had good motivating powers and therefore had will to fight and would not stop unless he was severely wounded.

(3) The wounded soldier was near a first aid station so that if he were severely wounded and realized that his life would probably be saved if he went back to the first aid station, he would do so rather than continue fighting.

(4) Areas such as hands, feet, and skin surface not near important blood vessels were excluded from the total target area, since, should wounds be inflicted in these areas, a severe wound would not be produced regardless of the mass or the velocity of the bullet. This excluded area is equivalent to 15% of the total body area.

(5) It was assumed that upon impact none of the bullets would tumble, deform or break up. Actually for the smaller caliber bullets, this is a pessimistic assumption for they tend to tumble more readily than bullets of larger caliber due to the reduced transverse moment of inertia.

Dr. Odell's estimates of the probability of a severe wound as related to striking velocity are plotted in Figure 5. These estimates are based on his understanding of the effects of caliber and velocity on the size of the maximum temporary cavity in gelatin molds, which is considered to be a good measure of the severity of the wound and also of the rate of incapacitation. Figure 6 shows these data replotted to a relative basis, using the Cal. .30 M-1 rifle M-2 Ball ammunition as a standard.

To determine the single shot probability of hitting and then incapacitating, relative to the Cal. .30, the hit probability was multiplied by the probability of a severe wound and then divided by the corresponding product for the Cal. .30 M-1 rifle. This relative single shot effectiveness has been plotted in Figure 7.

To determine the relative expected number of kills per soldier, the relative single shot probability of a kill was multiplied by the ratio of number of rounds carried with a given gun as shown in Table II to that carried with the M-1 rifle. This is plotted in Figure 8.

Since the wound ballistic estimates of Dr. Odell were based on limited experimental data, a check on the results was made using the wound criteria developed by Dr. T. E. Sterne* of BRL from experiments conducted by the Biophysics Branch, Medical Laboratories, Army Chemical Center, Maryland. Dr. Sterne has determined the probability of incapacitation as a function of MV/A, where M is the mass in grams, V the striking velocity in cm per sec, and A the average presented area in sq. centimeters. The resulting curves from Dr. Sterne's report have been reproduced in this report in Figure 9. Also shown are the Odell curves replotted to the same abscissa.

It should be noted that the Sterne wound criterion was developed for fragments and it is not expected to be more than very roughly valid for bullets. The quantity MV/A is a measure of ability to penetrate and should therefore determine the probability that if a bullet hits it will pass through protective clothing, [illegible] and bone, and reach certain vital organs. However, the "A" appropriate to penetration through clothing, skin, and body-wall should probably be the minimum cross-section of the bullet while after the bullet has penetrated the body-wall it tends to tumble, and such tumbling should be expected not only to influence the amount of damage caused by the bullet to vital organs in or near its path, but also to increase its effective area A. The criterion in its present form, appropriate to fragments, has not been designed to take into account the phenomenon of a bullet entering the body with a small A and then, by tumbling, acquiring a larger A. In order to use Sterne's criterion some value had to be given to the quantity A, and the value used was the tumbling value, one-fourth of the total superficial area. Therefore the penetrating power of the bullet was underestimated during its passage through the outer protective layers, and it is felt that an underestimate has consequently been made of the probability of incapacitation from a random hit.

Figures 10, 11, and 12 show the relative single shot probabilities of hitting and incapacitating of the various guns using Dr. Sterne's wound criteria for 5 sec., 5 min., and "B" kills. Figures 13, 14, and 15 show the overall expected number of kills where the number of rounds carried is considered.

RESULTS

There is little difference between the results obtained from Odell's criterion and Sterne's criterion. Although Odell's shows a much higher

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* Technical Note No. 556

single-shot wounding probability, when the rifles are all compared to the M-1 as a standard, there is very little difference. According to Sterne's curves, the effectiveness for quick incapacitation of the lower-powered, smaller caliber rifles drops off considerably at the longer ranges. However, the effectivness for lower rates of incapacitation or "B" kills is still high and it may be argued that a high rate of incapacitation is in general not required at long ranges.

In general it can be stated that if the combined weight of rifle and ammunition is fixed at 15 lbs., a man carrying the Cal. .21 rifle would have an expectation of killing about 2-1/2 times as many targets as with the M-1 rifle. The range at which this occurs depends on the amount of charge. The 0.6 charge rifle is most effective at the short ranges because of the lighter ammunition. The 1.0 charge is most effective at the longer ranges because of its flatter trajectory.*

The final curves of relative overall expected number of kills show that rifles with heavy charges are preferable at the longer ranges, but those with the lighter charges are made preferable at the short ranges. It is beyond the scope of the present report to state which is the optimum rifle, for this would depend on the most probable combat range. An indication as to this range may be obtained from a report of a wound ballistic survey in Korea. A curve based on data from this report is reproduced in Figure 16. This shows estimated ranges at which rifle hits were obtained. The mean range is about 120 yards. At ranges greater than 300 yds. less than 10% of the hits were obtained. From this it might be concluded that a rifle that is more effective at ranges up to 500 yds. should be favored over one that is more effective at ranges greater than 500 yds. This conclusion is independent of the frequent use of the rifle for inaccurate fire at longer ranges, since all of the rifles considered will be lethal to two thousand yards although at such ranges the probability of hitting will be negligible.

---

* Due to the fact that wound ballistic data are lacking on the caliber .30 carbine, this gun was not shown in the curves of this report. However, estimates on the wound ballistics by the author show that at 300 yds. the single shot effectiveness is approximately one-half that of the standard M-1 rifle. This is due to the low muzzle velocity (1970 fps). Since the carbine is quite light it would take 240 rounds to bring the total weight of gun and ammunition to 15 lbs. Therefore the overall effectiveness is high at very close ranges but falls off rapidly for increasing ranges so that it is the least effective for all the guns for ranges greater than 300 yds.

EXPERIMENTAL DATA ON A .220 RIFLE

During the course of this study a number of conclusions were questioned because of the fact that the popular commercial .220 Swift rifle is generally felt to be less effective as a hunting rifle than a 30-06 rifle. Actually the .220 Swift cannot be reasonably compared with any of the rounds in the present study, because these rounds all involved scaled-down versions of the excellent Cal. .30 Ball M-2 bullet, and therefore have considerably better ballistic characteristics than the inferior .220 Swift. The .220 Swift has a 48 grain, soft nose bullet in contrast to the 60 grain Cal. .22 bullet, of the present study, that would be homologous to the Cal. .30 Ball M-2.

Through the assistance of Col. Studler of the Ordnance Office, a rifle and 200 rounds of ammunition were acquired with a bullet shape that was nearly, but not quite homologous to the Cal. .30 Ball M-2. The homologous Cal. .22 bullet would be a 60 grain bullet having a 7.0 Cal. radius tangent ogive and be 0.825" long. The rounds received had a 6.0 Cal. radius tangent ogive, were 0.76" long, and weighed 60 grains. As a result, the experimental ammunition had a ballistic coefficient of 0.13 (by actual measurements) as compared to 0.18 (calculated)* for the homologous bullet. This information is shown in the form of curves of remaining velocity vs. range in Figure 17. Ballistic data are also shown for the .220 Swift and Cal. .30 M-1 rifle. Figure 18 shows the effect of cross wind on both the Cal. .22 and Cal. .30 bullets. These curves were taken from nomograms by Coxe and Bugless appearing in Johnson and Haver's book "Ammunition". It is noted that there is little difference between the two rifles.

The 200 rounds of Cal. .220 ammunition were fired in a special Winchester rifle with a 10" twist to obtain ballistic, accuracy, and penetration data. This work was performed by the Small Arms Section of D&PS**, and a condensation of the results is shown in Table III. All accuracy data were made with a telescopic sight and the rifle was on a bench rest so as to eliminate as much as possible the aiming errors.

The results of these tests show that if the Cal. .22 bullet is made with a weight of 60 grains and a 6.0 cal. tangent ogive, it will have good accuracy and ballistic characteristics. If the bullet can be designed with a 7.0 Cal. tangent ogive, its ballistic characteristics will be considerably improved, and its effective range increased about 25%.

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* Mr. H. P. Hitchcock of BRL assisted the author in making ballistic computations. His help in this matter is greatly appreciated.

** Appreciation is expressed to Mr. G. A. Gustafson and Mr. William Davis of D&PS for their cooperation with these tests, and for their valuable advice.

An interesting comparison is made in the ability to penetrate 10 gauge (.137") cold rolled sheet steel. The experimental Cal. .220 round gave complete penetration at 500 yds. (or 1800 ft/sec velocity) and partial penetration at 600 yds. (or 1600 ft/sec). A Cal. .30 Ball M-2 round will completely penetrate the same 10 gauge steel at 625 yds. (or 1400 ft/sec) and partially penetrate at 725 yds. If, however, the Cal. .22 was made with a 7.0 Cal. tangent ogive (so as to give it the same form factor as the Cal. .30), the range at which the velocity would drop below 1800 ft/sec would be 700 yds. or approximately equal to the Cal. .30. This is not unreasonable when it is considered that the value of $MV^{4/3}/A$, where M is the bullet mass, V the striking velocity, and A the maximum diametrical area, is practically the same at these velocities for both the Cal. .30 and .22.

Due to the limited supply of ammunition, it was not practicable for the Army Chemical Center to determine the wound ballistic characteristics. Therefore, to get an indication of wound ballistics, firing was conducted against 5" cubes of "Plastilina" modeling clay. To obtain reduced striking velocities the rounds were fired with reduced loads. The results of these tests are shown in Figure 19, where the resulting cavity volume, entrance and exit holes, are shown plotted against striking velocity. Photographs of the molds are in Figures 20 through 23A. This was a rather small sample of experimental data and it is doubtful if any firm conclusions can be drawn from it. However, if it could be assumed that a bullet will behave in flesh the same way as it did in the modeling clay, and if the size of the cavity were a measure of the severity of the wound, it could be concluded that for the same striking velocity, the Cal. .220 is practically as effective as the Cal. .30. This may be due to the fact that the Cal. .220 appeared to tumble in the clay at all the velocities considered. Furthermore, under the above assumptions, since the Cal. .22 will have a higher striking velocity than the Cal. .30, the severity of the wound for a given range should be much greater for the Cal. .22 than for the Cal. .30.

To illustrate the above point, the diameter of the exit cavity as shown in the curves of Figure 19 has been replotted as a function of range for the Cal. .30, the experimental Cal. .220 and for the homologous Cal. .22 which has the improved ballistic coefficient. This is shown in Figure 24.

SUMMARY

The theoretical consideration of a family of rifles indicates that smaller caliber rifles than the .30 have a greater single-shot kill probability than the Cal. .30 M-1. This is obtained by increasing the muzzle velocity and thereby obtaining a flatter trajectory, so that the adverse effect of range estimation errors is reduced. When the combined weight of gun and ammunition is held constant at 15 lbs. the overall expected number of kills for the Cal. .21 rifle is approximately 2.5 times that of the present standard Cal. .30 rifle. If the number of rounds is fixed

at 96, the total load carried by a soldier with a Cal. .21 rifle and ammunition with 6/10 the charge in the M-2 cartridge will be 3.6 lbs. less than that carried by a soldier with a Cal. .30 M-1 rifle. This is a 25% reduction in load.

Furthermore, if it were necessary for a soldier with the M-1 to carry the rounds required for the same expected number of kills at 500 yds. as a soldier with 15 lbs. of Cal. .21 6/10 charge rifle and ammunition, it would be necessary for him to carry 10 lbs. more ammunition or a total load of 25 lbs.

The experimental data on a high velocity Cal. .220 rifle tend to substantiate the conclusions of the theoretical study.

The conclusions using Odell's wounding estimates agree with those obtained using Sterne's criterion.

It is recognized that this study has not considered the practicability of building the smaller caliber rounds or rifles and that this may limit the choice of the optimum caliber. It is hoped that this report will stimulate comment on this from arms manufacturers*.

CONCLUSIONS AND RECOMMENDATIONS

A smaller caliber, higher velocity rifle than the Standard Cal. .30 is more effective than the Cal. .30 when compared on the single-shot basis; the basis of equal combined weight of rifle and ammunition, the basis of load required for equal amount of ammunition carried, and on the basis of load required for an equal number of targets killed.

It is recommended that tests be conducted to determine the following information:

(a) Single-shot hit probability as a function of range, muzzle velocity and obstacles such as brush and vegetation.

(b) Probability of causing certain types or rates of incapacitation as a function of striking velocity and projectile weight.

(c) Effect of recoil on the probability of hitting for semi-automatic and automatic rapid fire.

The author would be grateful for comments from the using services, from arms designers, and from arms manufacturers.

---

* The effect of barrel erosion at high muzzle velocities has been considered. It is not expected to be important with the improved powders, because accuracy life is expected to exceed service requirements.

Donald L. Hall

Donald L. Hall

TABLE I

Ratio of Charge Weight to Weight of Charge for Cal. .30 M-2 Ball Ammunition	Caliber (inches)	Bullet Weight (Grains)	Charge* Weight (Grains)	Muzzle* Velocity f/s	Kinetic Energy of the Bullet ft-lbs.
1	.21	52	53	4272	2120
	.24	78	53	3652	2320
	.27	111	53	3149	2460
	.30	152	53	2740	2550
8/10	.21	52	42	3921	1680
	.24	78	42	3329	1930
	.27	111	42	2856	2020
	.30	152	42	2476	2080
6/.	.21	52	32	3485	1410
	.24	78	32	2937	1500
	.27	111	32	2507	156
	.30	152	32	2167	15[illegible]

* Data for this table was extracted from a report prepared under the direction of Mr. R. H. Kent entitled "Maximum Ordinate and Striking Energy for Several Ranges and Free Recoil Energy vs. Caliber for Rifles of Several Weights". Ballistic Research Laboratories, October 1950.

The assumption of constant Kinetic Energy for rifles of different calibers presents some difficulties which are not felt to be insuperable. Modern methods of controlling burning rates of powders furnish a possible answer to these difficulties.

TABLE II

Ratio of Charge Weight to Weight of Charge for Cal. .30 Ball M-2 Ammunition	Caliber (inches)	Rifle Weight Reduction From M-1 (lbs.)	No. Rounds* for Total Weight of 15 lbs.	Weight Reduction for Rifle and Only 96 Rounds (lbs.)
1.0	.30	.00	96	.0
	.27	.06	108	.6
	.24	.12	122	1.2
	.21	.18	135	1.6
.8	.30	.31	118	1.1
	.27	.37	136	1.7
	.24	.43	151	2.1
	.21	.49	170	2.6
.6	.30	.62	142	2.0
	.27	.68	166	2.6
	.24	.74	194	3.1
	.21	.80	224	3.6

* Weight of Cal. .30 M-1 rifle 9.6 lbs.

Weight of Cal. .30 Ball M-2 Round, less clip .057 lbs.

TABLE III

Bullet Weight	60 grains
Bullet Length	.76", 6 caliber tangent ogive
Charge	40.5 grains IMR 6362, Blend 9
Muzzle Velocity	3660 fps

Ballistic Coefficient, using G_6 tables = .132

ACCURACY

Range (yds)	No. of Rounds	Extreme Spread (inches)	Mean Radius (inches)
100	30	2.41	0.75
800	20	24.4	8.0

Penetration of 10 guage (.137 in.) mild steel plate:-

(1) Cal. .220, partial at 600 yds, complete at 500 yds.
(2) Cal. .30, M-2 Ball, partial at 725 yds, complete at 625 yds.

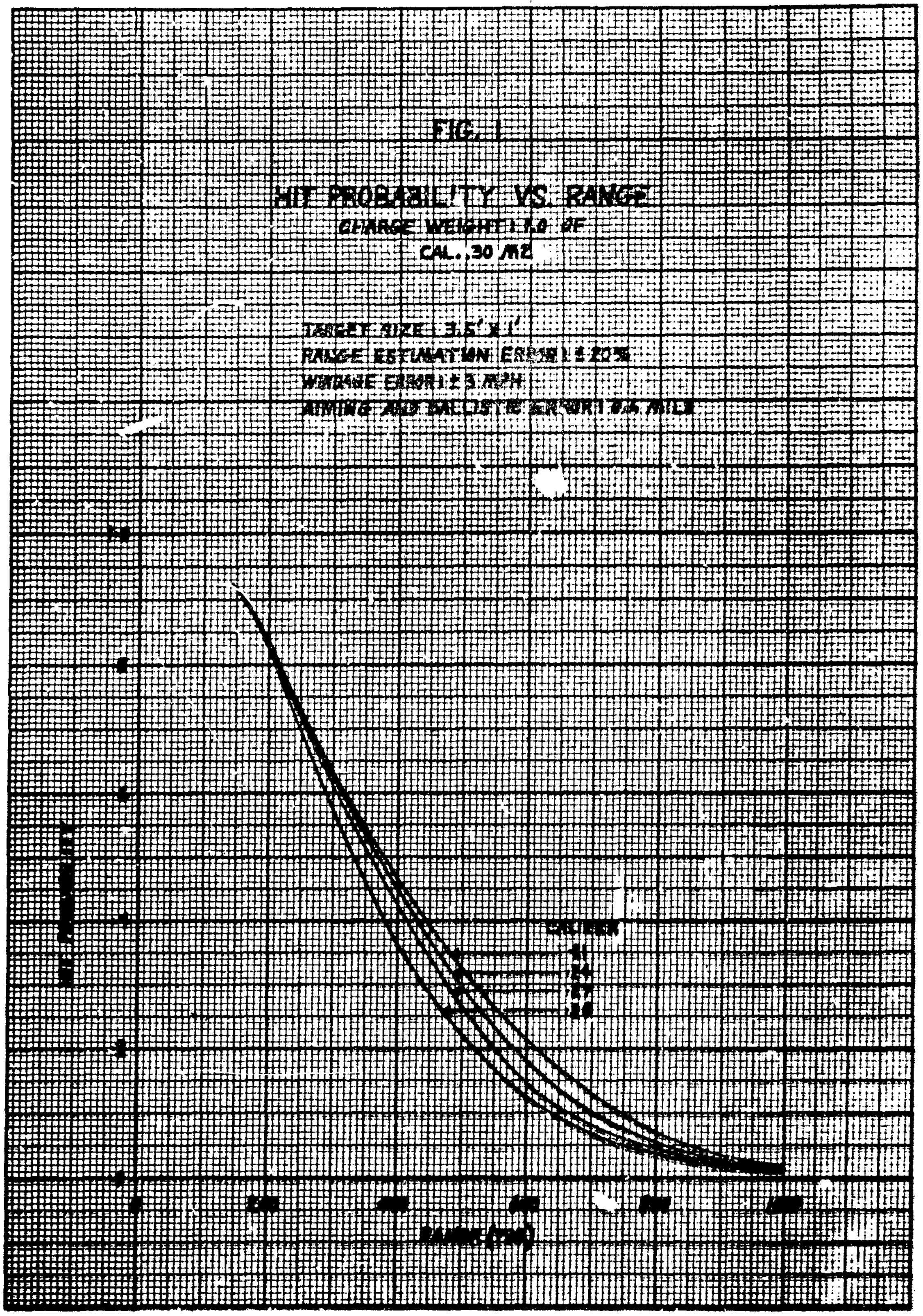


FIG. 1
HIT PROBABILITY VS. RANGE
CAL. .30 M2
TARGET SIZE: 3.5' x 1'
RANGE ESTIMATION ERROR: ±20%
WINDAGE ERROR: ±5 MPH

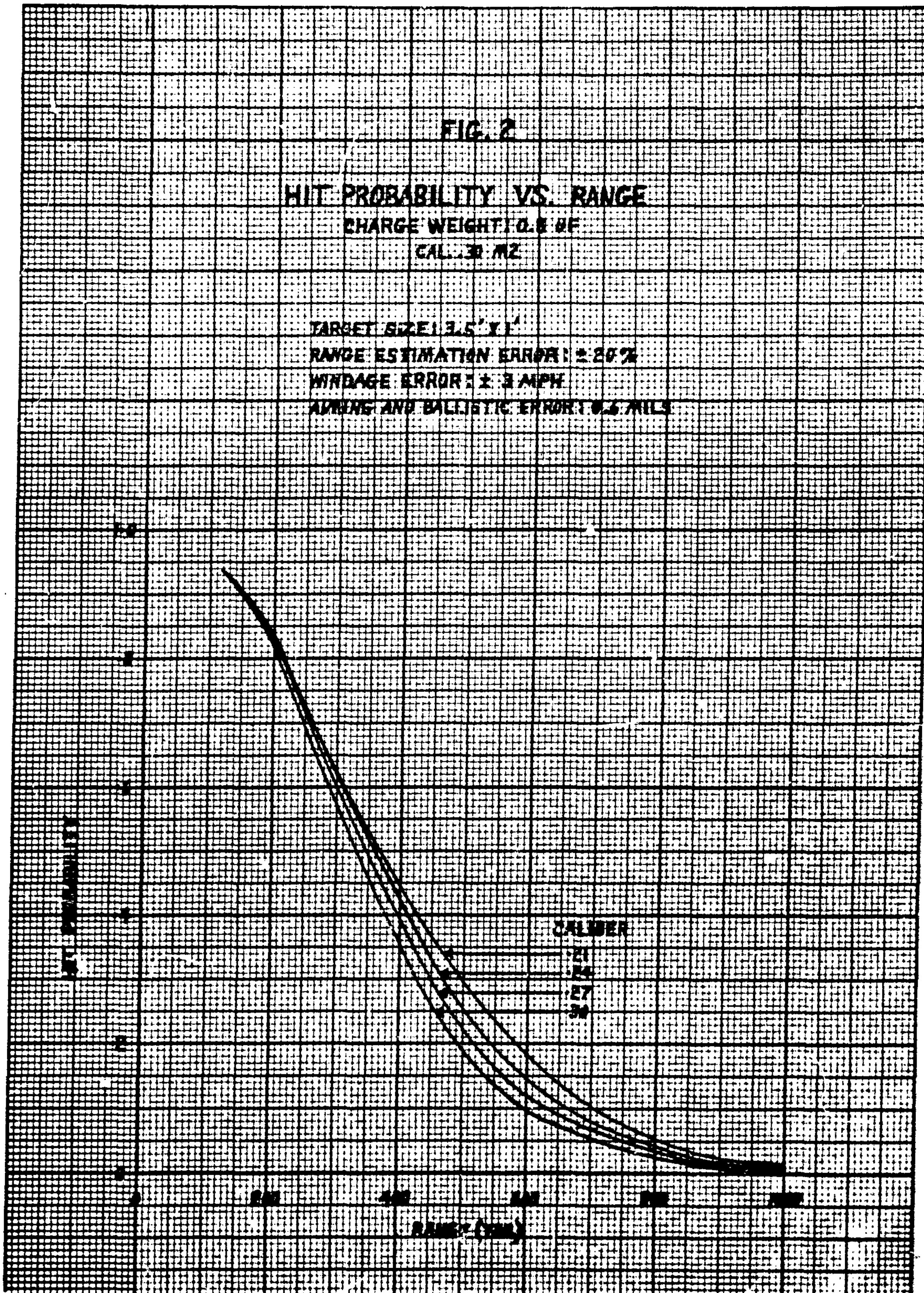


FIG. 2
HIT PROBABILITY VS. RANGE
CAL. .30 M2
TARGET SIZE: 3.5' X 1'
RANGE ESTIMATION ERROR: ± 20%
WINDAGE ERROR: ± 3 MPH
CALIBER
.21
.24
.27
.30

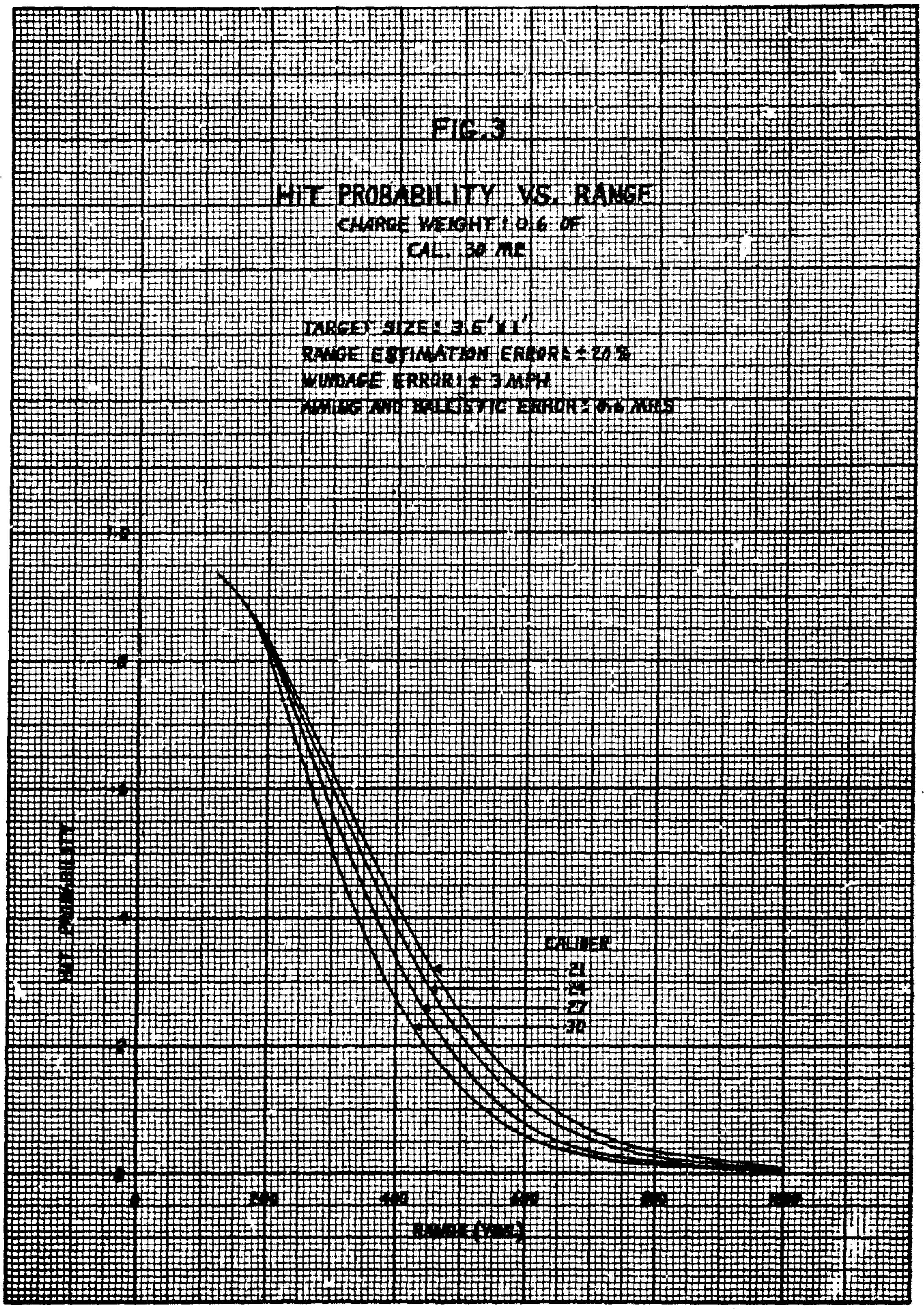


FIG. 3

HIT PROBABILITY VS. RANGE

CHARGE WEIGHT: 0.6 OF CAL. .30 ME

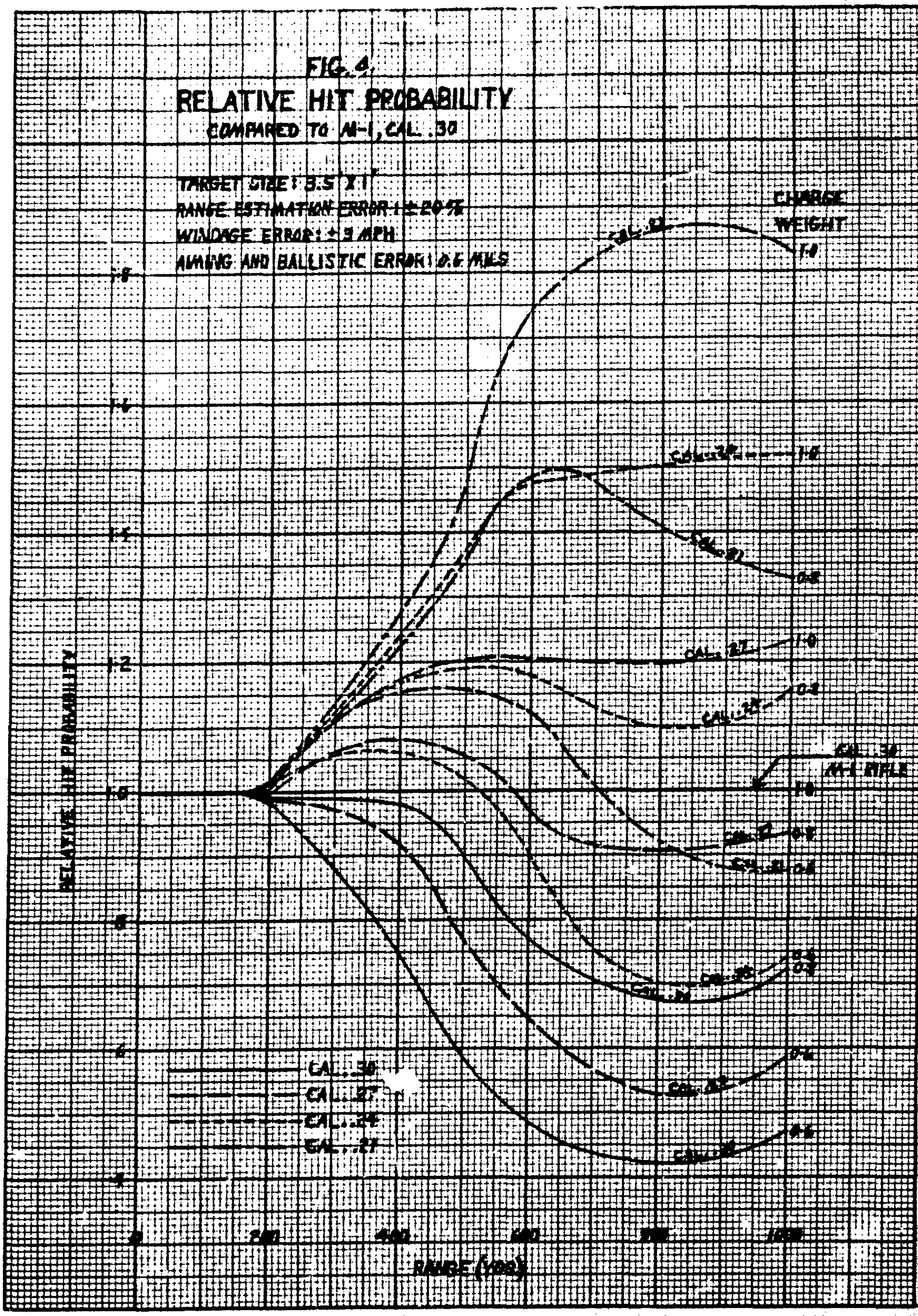


FIG. 4.
RELATIVE HIT PROBABILITY
COMPARED TO M-1, CAL. .30
TARGET SIZE: 3.5' X 1'
RANGE ESTIMATION ERROR: ± 20%
WINDAGE ERROR: ± 3 MPH
AIMING AND BALLISTIC ERROR: 0.6 MILS
CHARGE WEIGHT
CAL. .30
M-1 RIFLE
CAL. .30
CAL. .27
CAL. .24
CAL. .27
RELATIVE HIT PROBABILITY
RANGE (YDS)

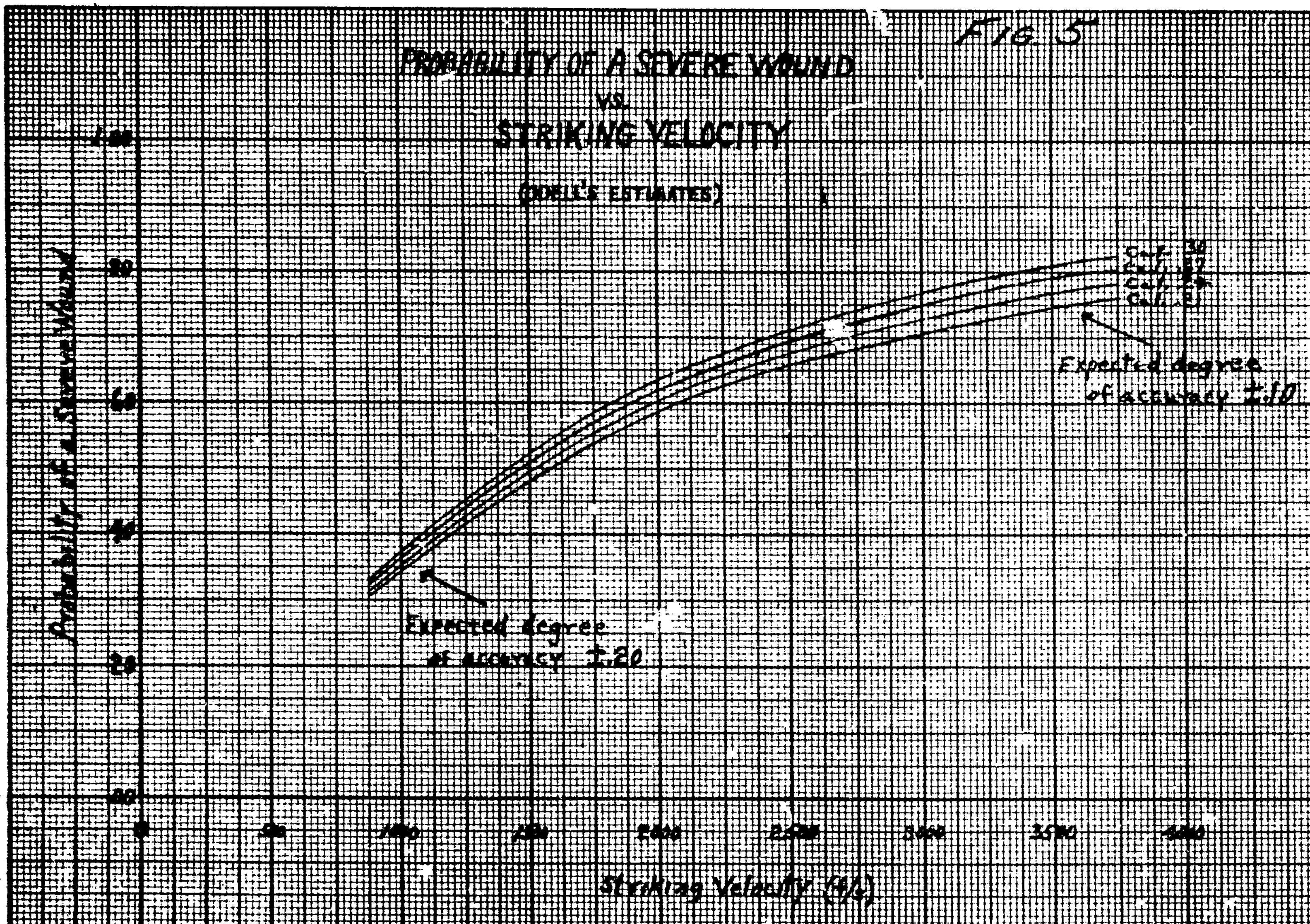


FIG. 5
PROBABILITY OF A SEVERE WOUND
VS.
STRIKING VELOCITY
(DOELL'S ESTIMATES)
Probability of a Severe Wound
Striking Velocity (ft/s)
Expected degree of accuracy ±10
Expected degree of accuracy ±20

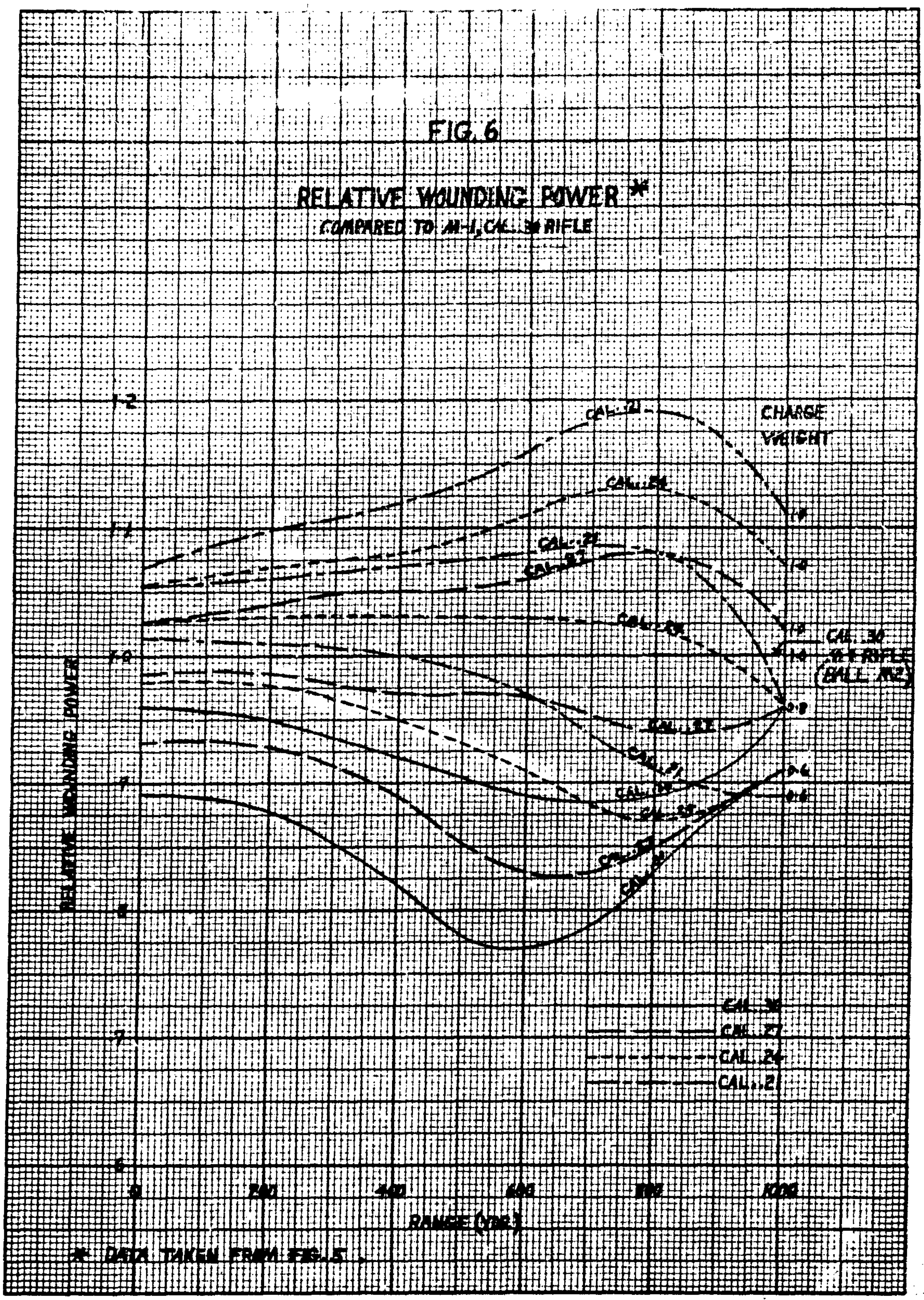


FIG. 6
RELATIVE WOUNDING POWER *
COMPARED TO M-1, CAL. .30 RIFLE
CHARGE WEIGHT
CAL. .30 M-1 RIFLE (BALL M2)
RELATIVE WOUNDING POWER
RANGE (YDS.)
CAL. .30
CAL. .27
CAL. .24
CAL. .21
* DATA TAKEN FROM FIG. 5

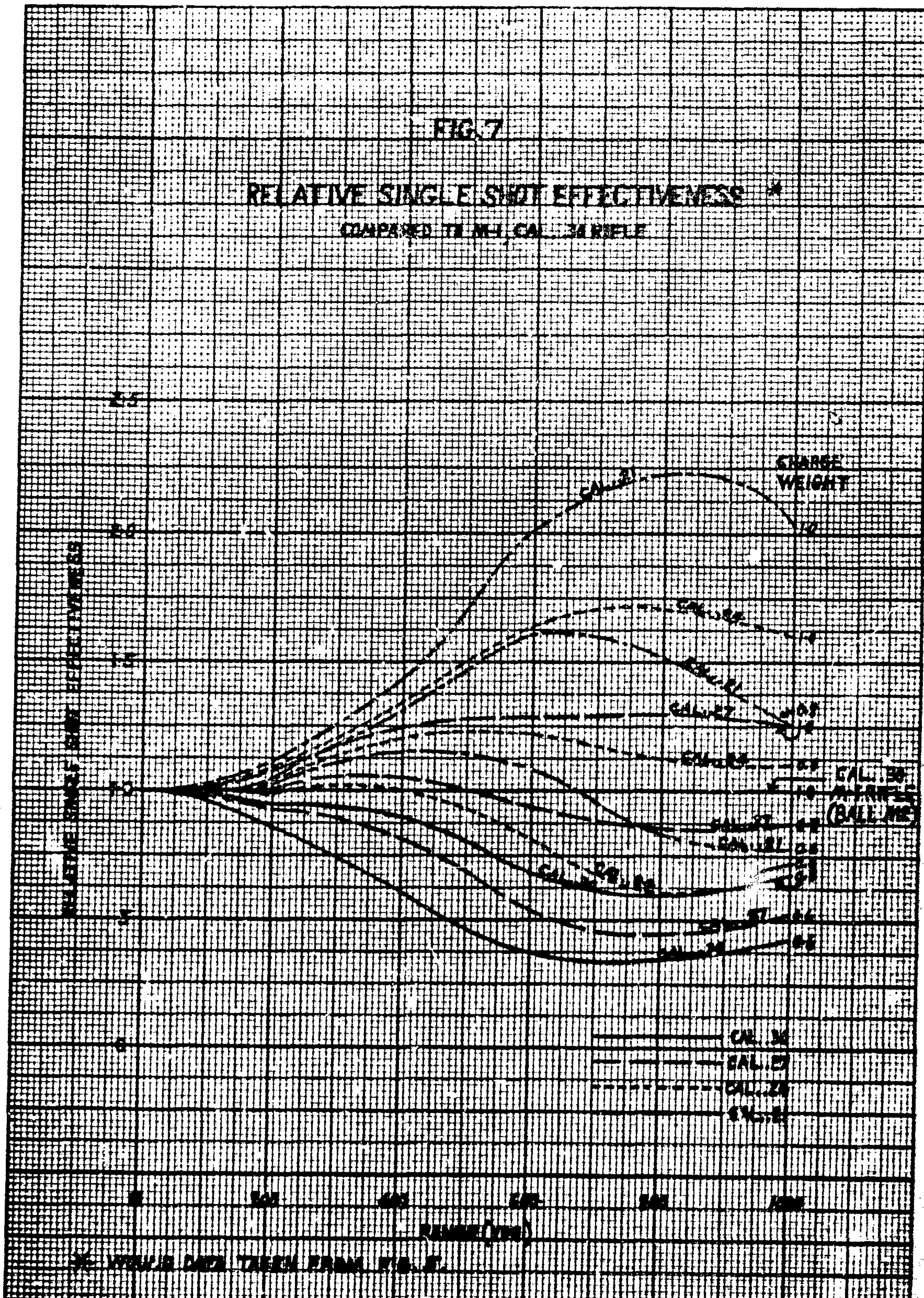


FIG. 7

RELATIVE SINGLE SHOT EFFECTIVENESS *

COMPARED TO M-1 CAL. .30 RIFLE

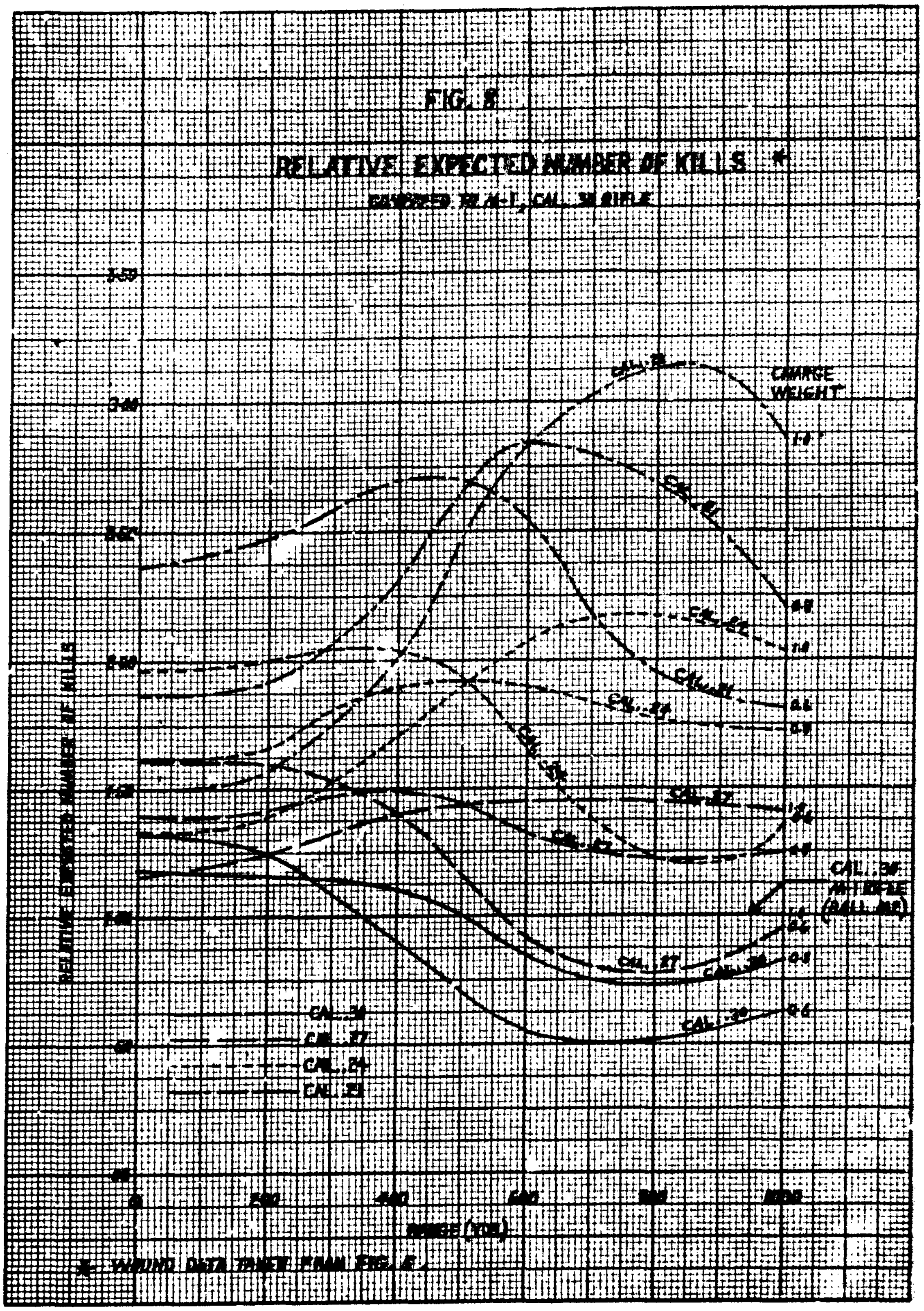


FIG. 8
RELATIVE EXPECTED NUMBER OF KILLS *
CHARGE WEIGHT
CAL. .30 M-1 RIFLE (BALL M2)

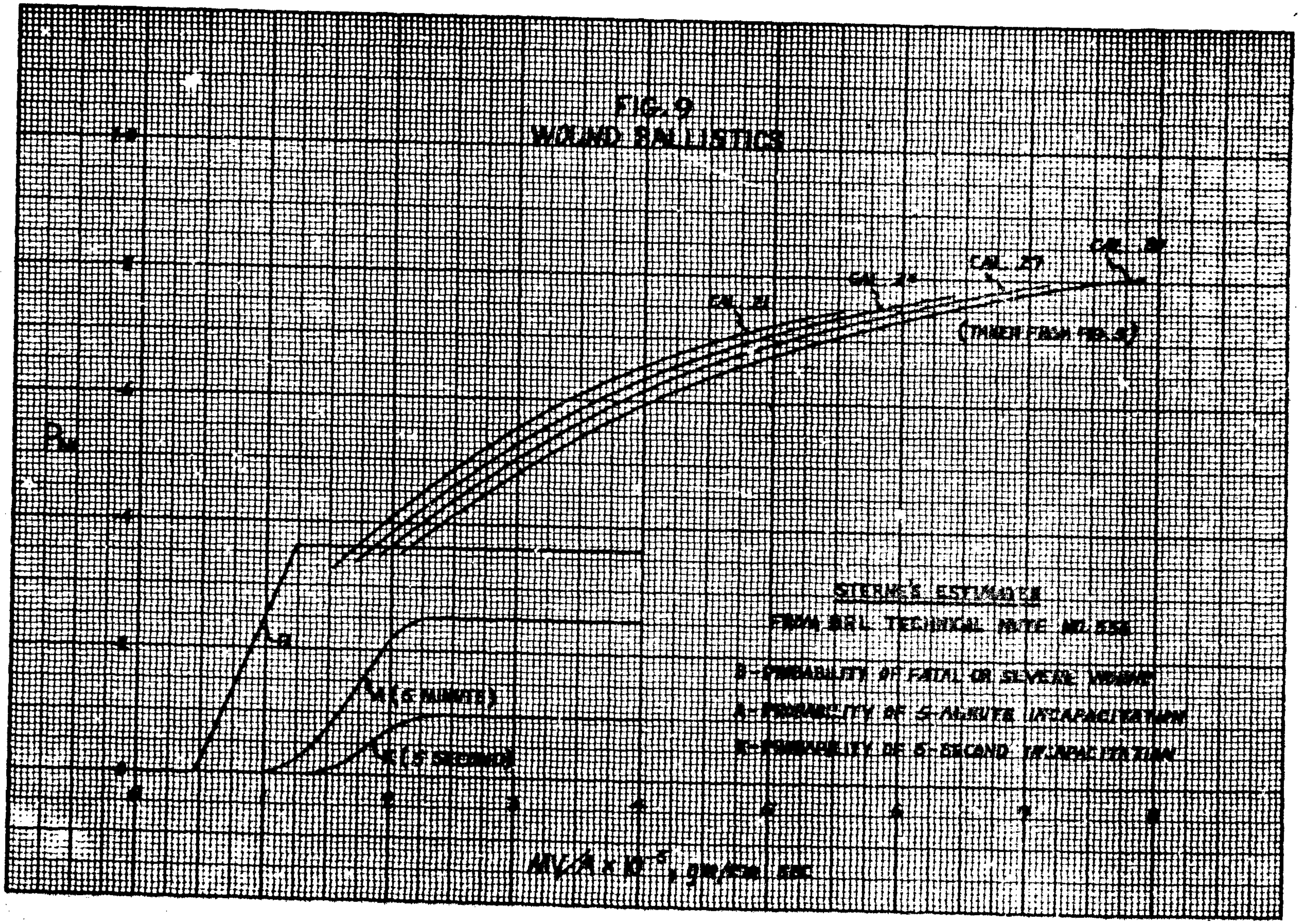


FIG. 9
WOUND BALLISTICS
STERNE'S ESTIMATE
B - PROBABILITY OF FATAL OR SEVERE WOUND
A - PROBABILITY OF 5-MINUTE INCAPACITATION
K - PROBABILITY OF 5-SECOND INCAPACITATION
A (5 MINUTE)
K (5 SECOND)
B
CAL. .21
CAL. .27

FIG. 10

RELATIVE SINGLE SHOT EFFECTIVENESS

COMPARED TO M-1, CAL .30 RIFLE

(STEPPE'S 5 SEC. WOUND CRITERION)

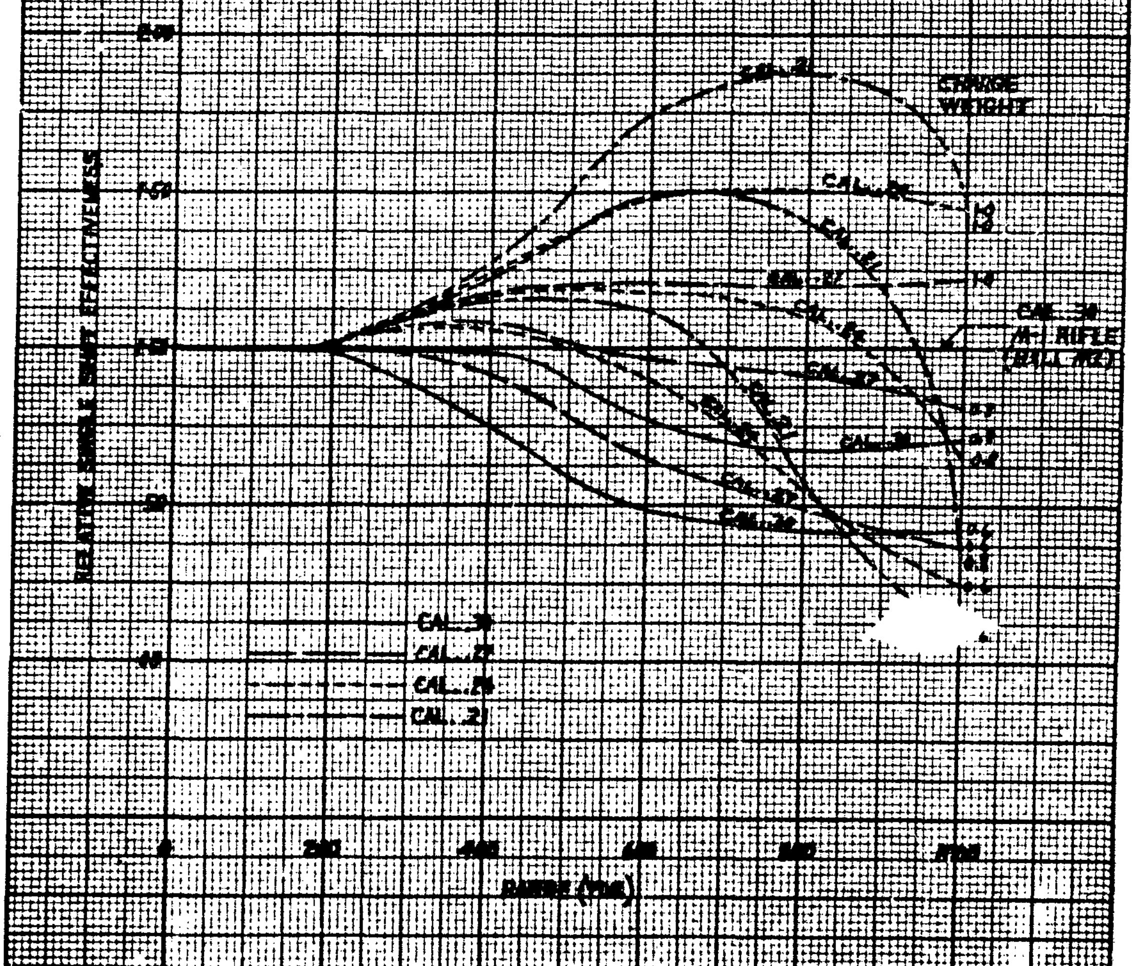
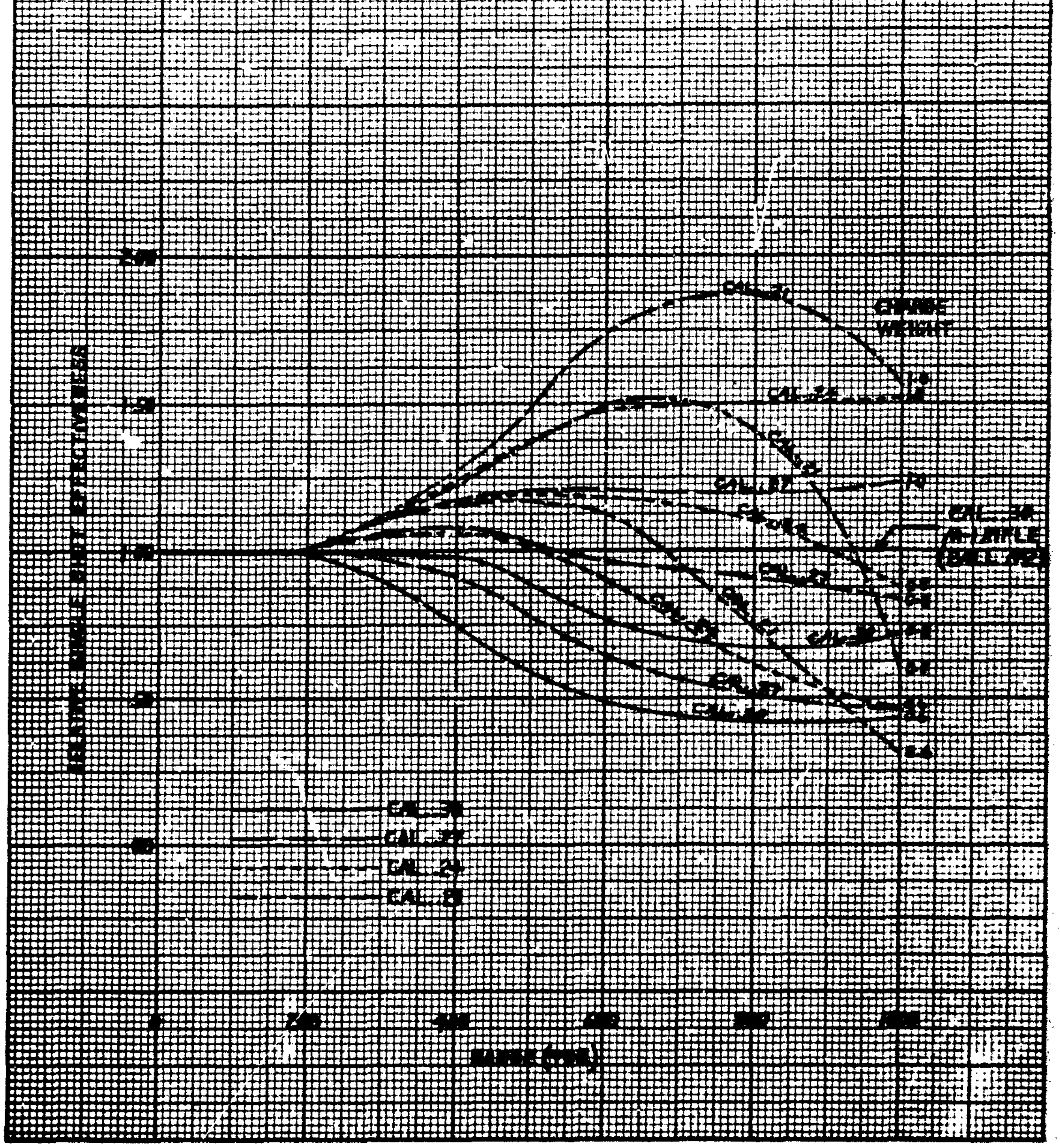


FIG. 11

RELATIVE SINGLE SHOT EFFECTIVENESS

COMPARED TO M-1, CAL. .30 RIFLE

(STERNE'S 5 MIN. WOUND CRITERION)



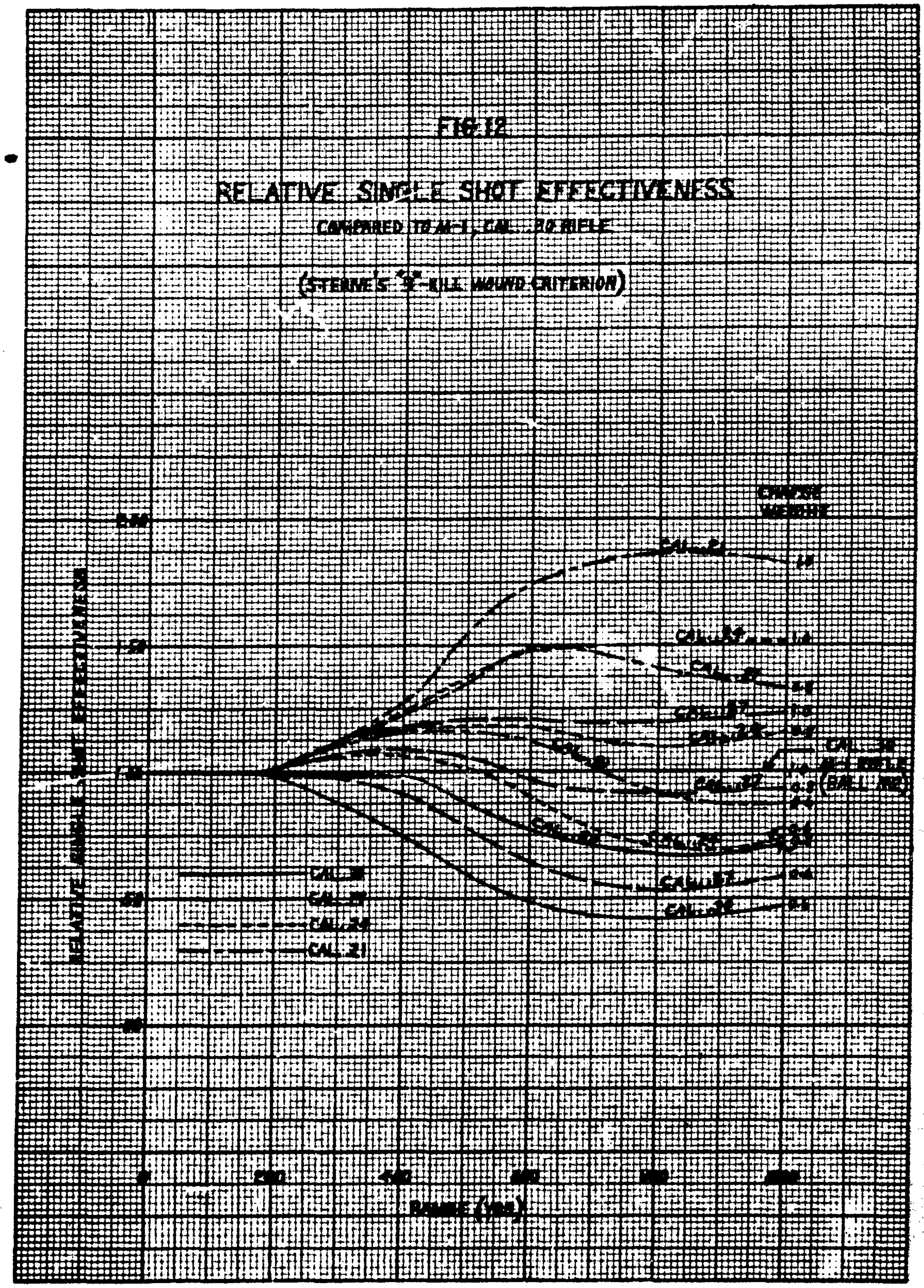


FIG 12
RELATIVE SINGLE SHOT EFFECTIVENESS
COMPARED TO M-1, CAL. .30 RIFLE
(STERNE'S "S"-KILL WOUND CRITERION)
CHARGE WEIGHT
RELATIVE SINGLE SHOT EFFECTIVENESS
CAL. .21
CAL. .25
CAL. .27
CAL. .30
M-1 RIFLE
(BALL M2)
CAL. .24
RANGE (YDS.)

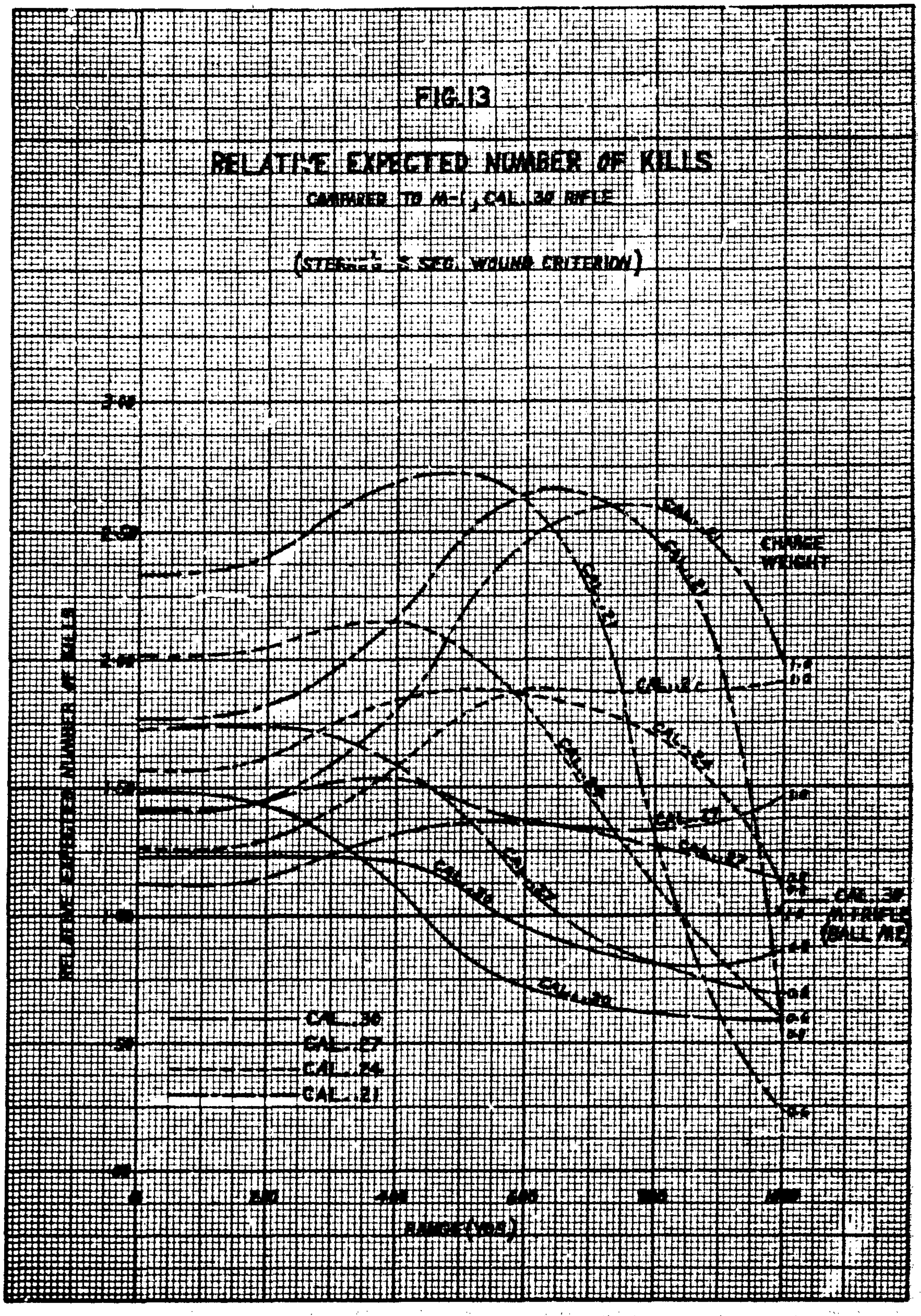


FIG. 13
RELATIVE EXPECTED NUMBER OF KILLS
CAL. .30 RIFLE
WOUND CRITERION
CHARGE WEIGHT
CAL. .21
CAL. .24
CAL. .27
CAL. .30
CAL. .30 M-1 RIFLE (BALL M2)
RANGE (YDS.)

FIG. 14

RELATIVE EXPECTED NUMBER OF KILLS

[illegible], CAL. .30 RIFLE

(STERNE'S 5 MIN. WOUND CRITERION)

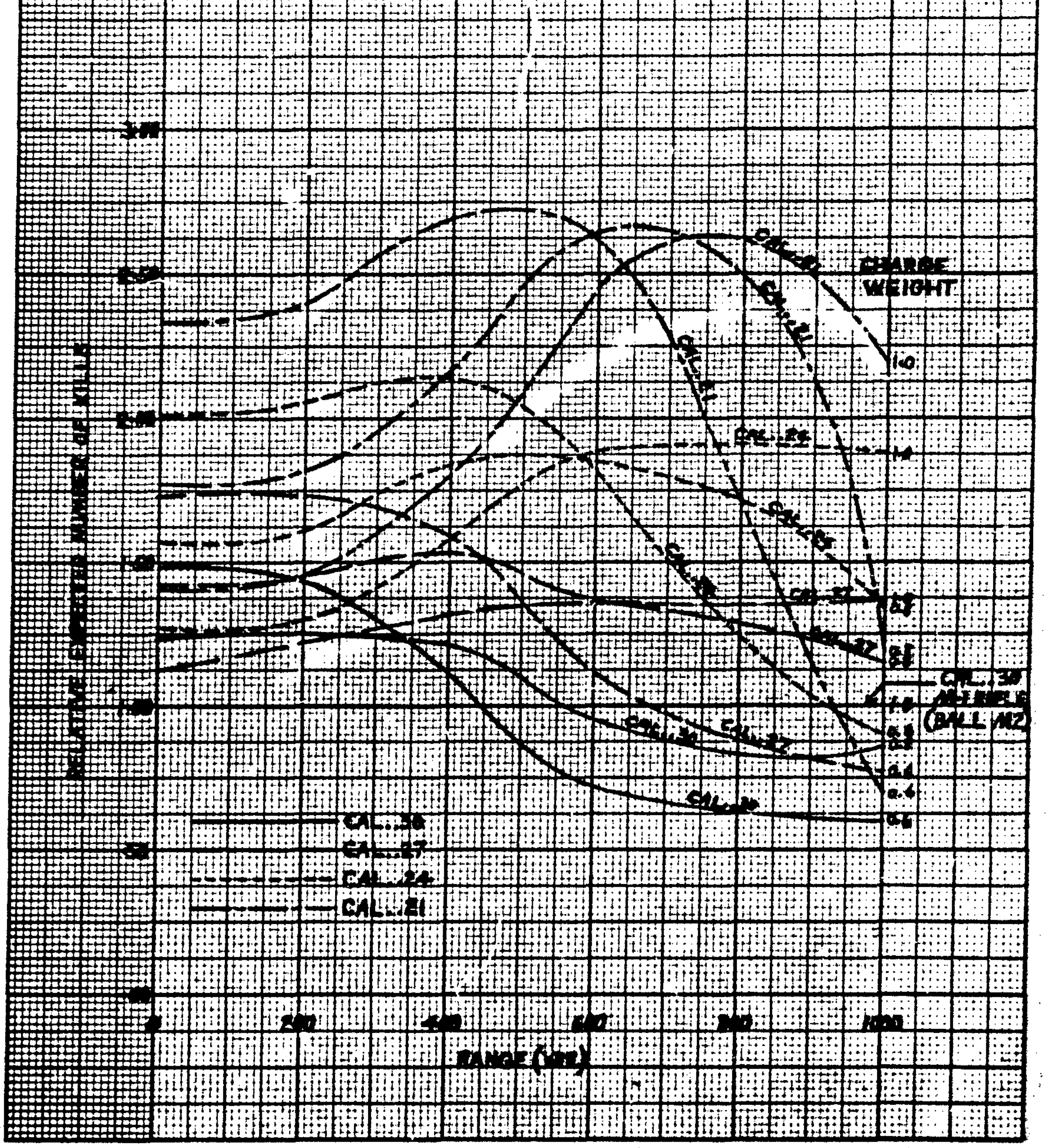
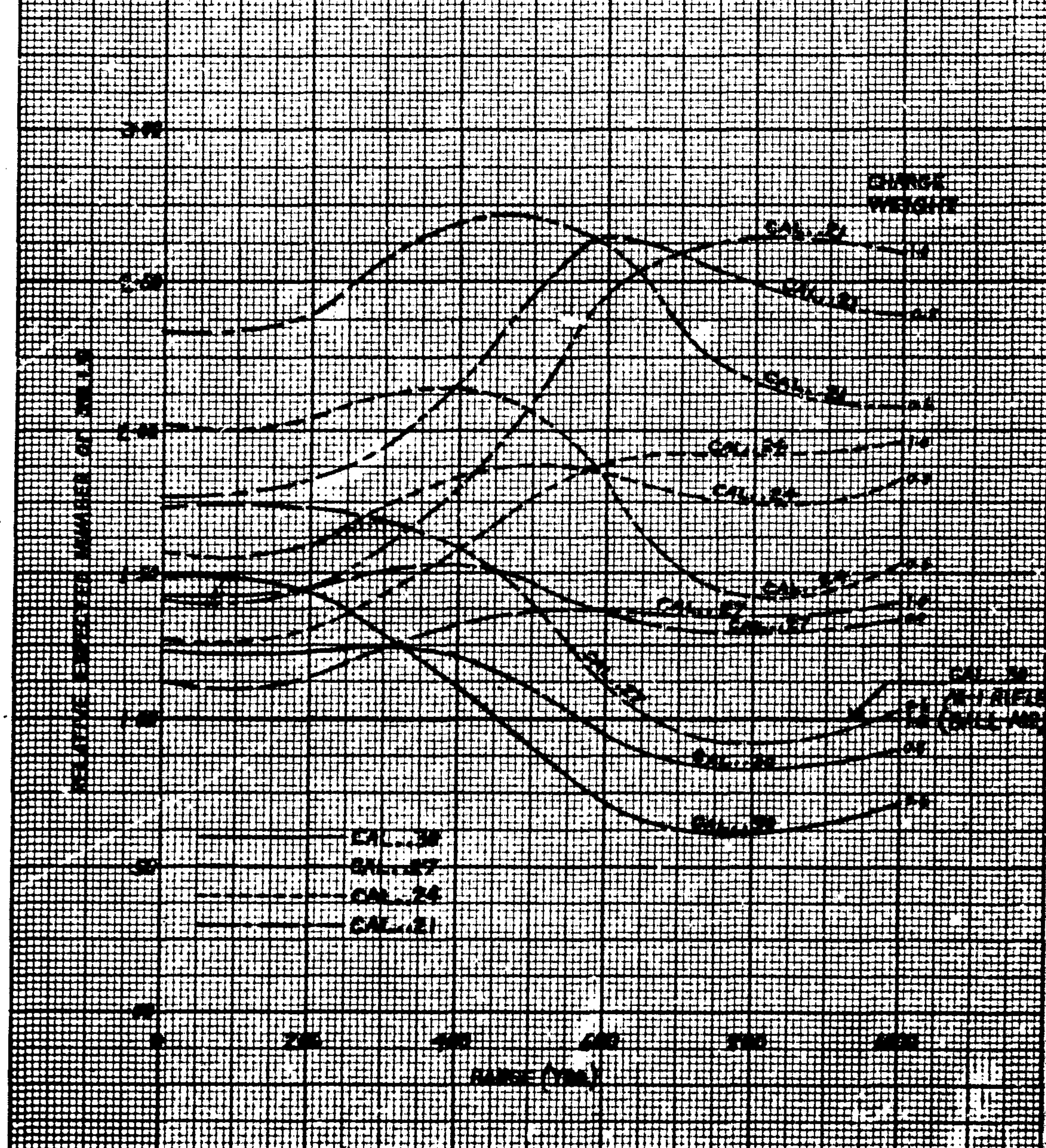


FIG. 15

RELATIVE EXPECTED NUMBER OF KILLS

COMPARED TO M-1, CAL. .30 RIFLE

(STERNE'S "A"-KILL WOUND CRITERION)



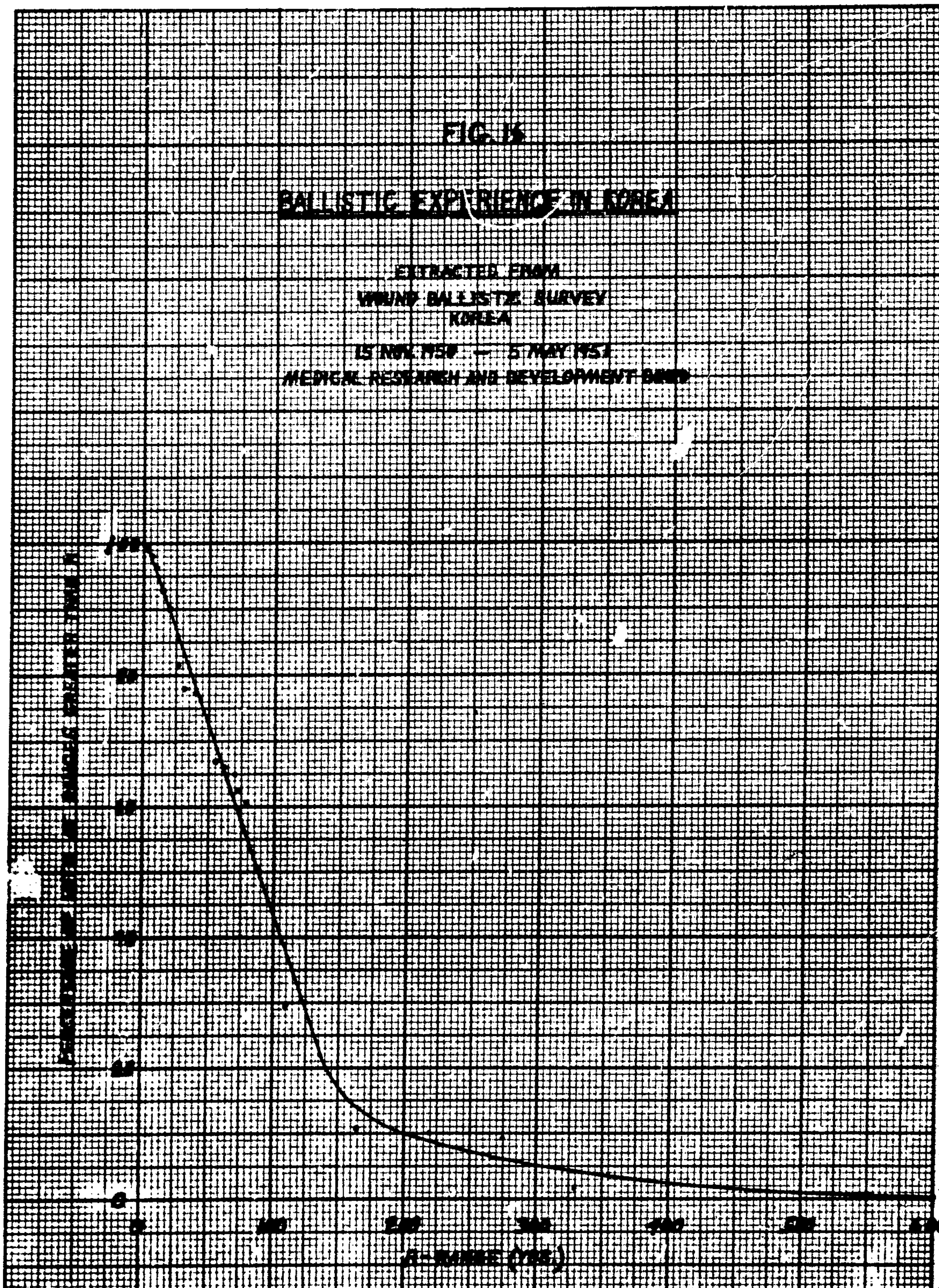


FIG. 16
BALLISTIC EXPERIENCE IN KOREA
EXTRACTED FROM
WOUND BALLISTIC SURVEY
KOREA
15 NOV. 1950 — 5 MAY 1951
MEDICAL RESEARCH AND DEVELOPMENT BOARD
0
100
200
300
400
500
600
R - RANGE (YDS.)

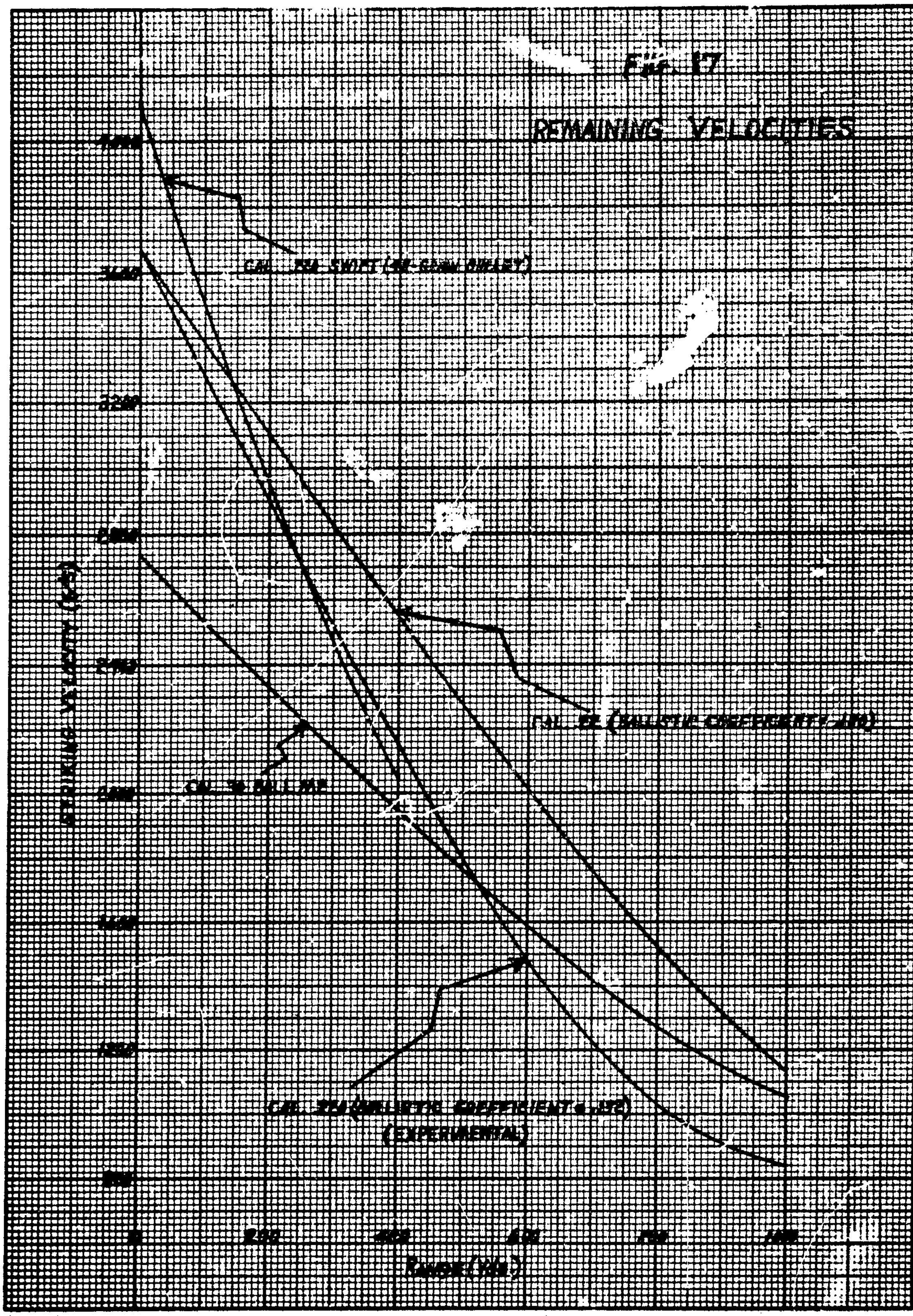


Fig. 17
REMAINING VELOCITIES
(EXPERIMENTAL)

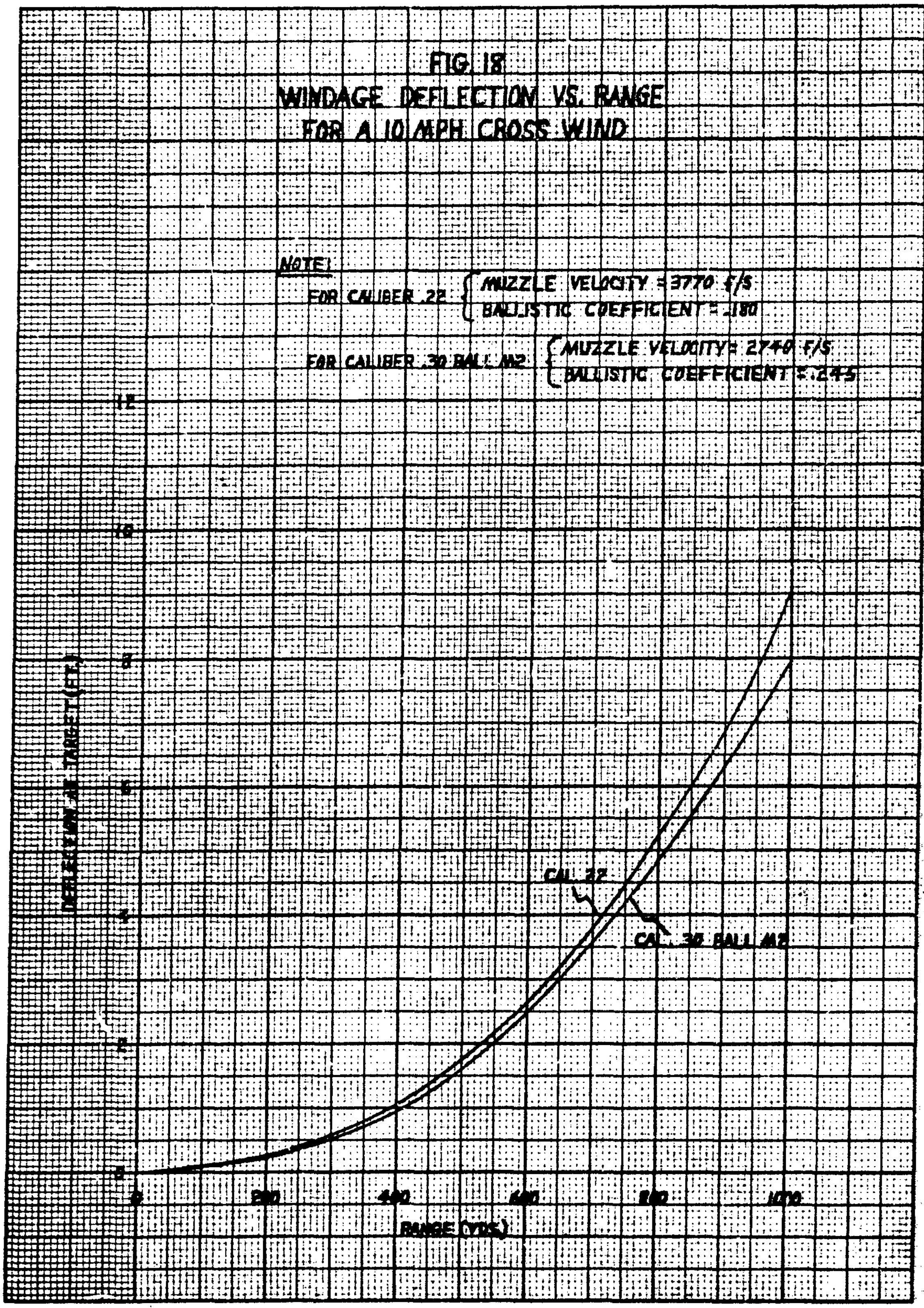
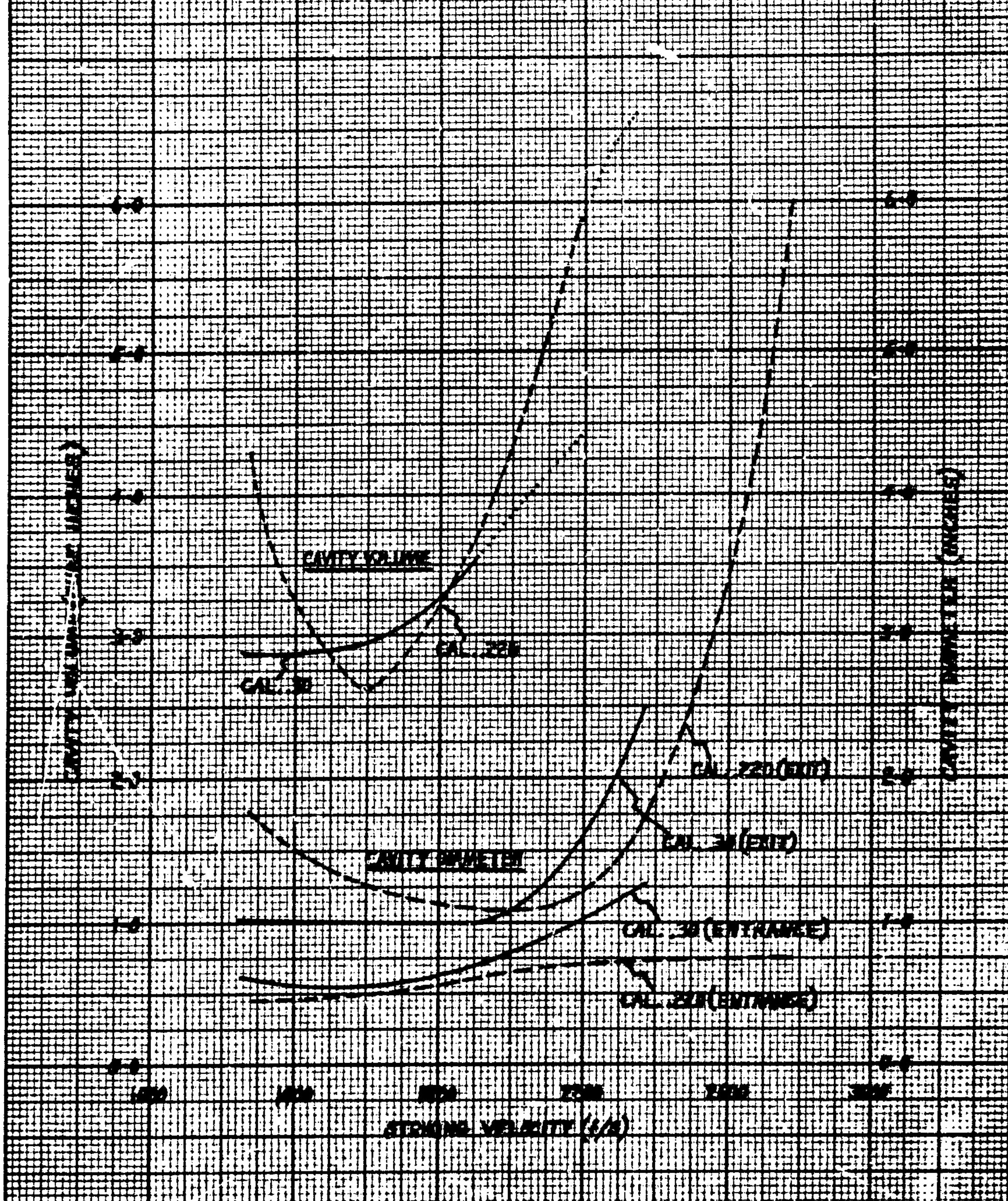


FIG 18
WINDAGE DEFLECTION VS. RANGE
FOR A 10 MPH CROSS WIND
NOTE:
FOR CALIBER .22 { MUZZLE VELOCITY = 3770 F/S
BALLISTIC COEFFICIENT = .180
FOR CALIBER .30 BALL M2 { MUZZLE VELOCITY = 2740 F/S
BALLISTIC COEFFICIENT = .245
CAL .22
CAL .30 BALL M2
DEFLECTION AT TARGET (FT.)
RANGE (YDS.)
0
200
400
600
800
1000
2
4
6
8
10
12

FIG.19

CAVITY SIZE IN 5-INCH MOLDS
OF MODELING CLAY



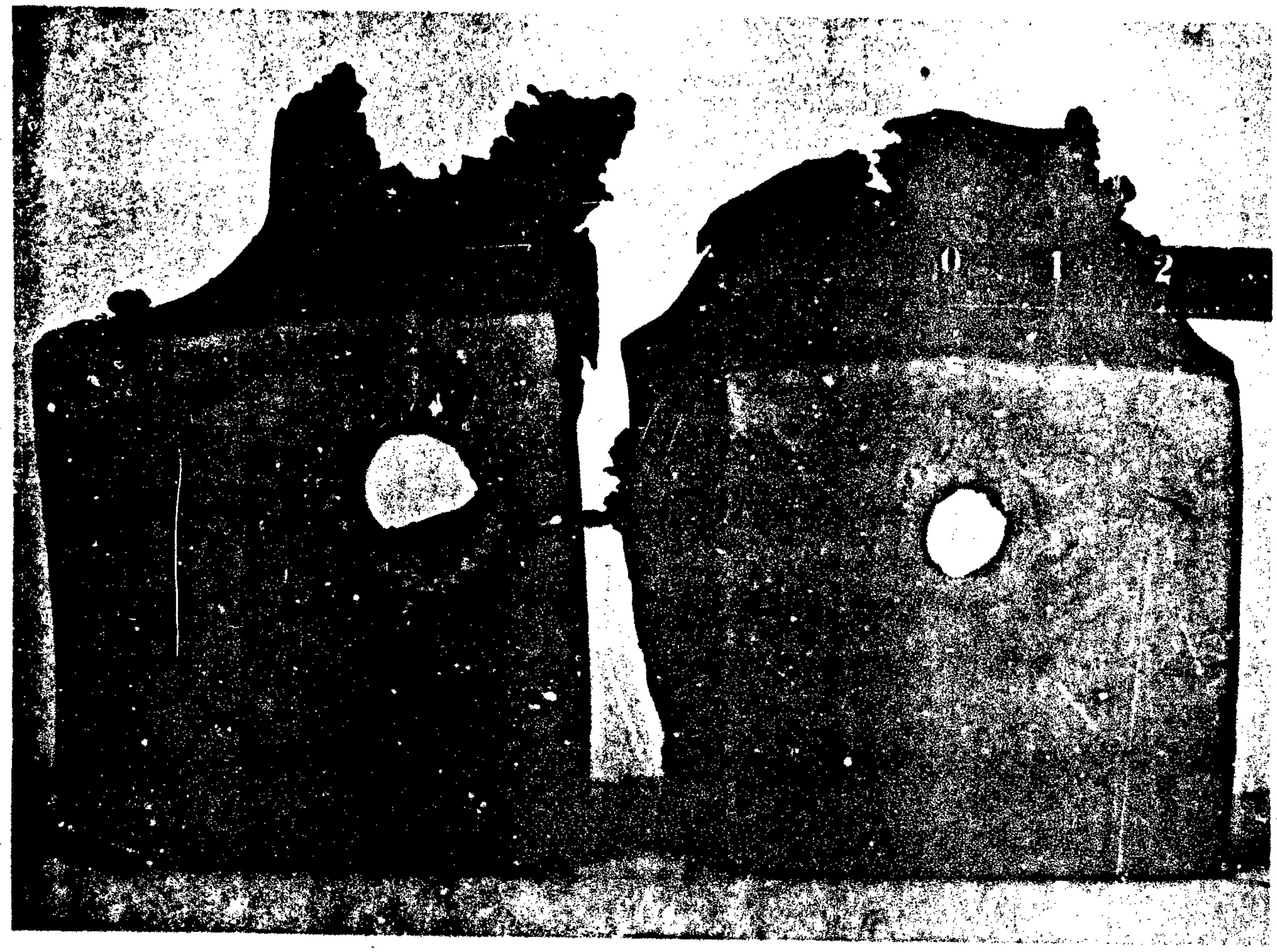


FIG. [illegible] (Entrance). Infantry Rifle Study.
LEFT: Caliber .30 Ball, M2. Velocity: 2380 f/s
RIGHT: Caliber .22. Velocity: 2770 f/s

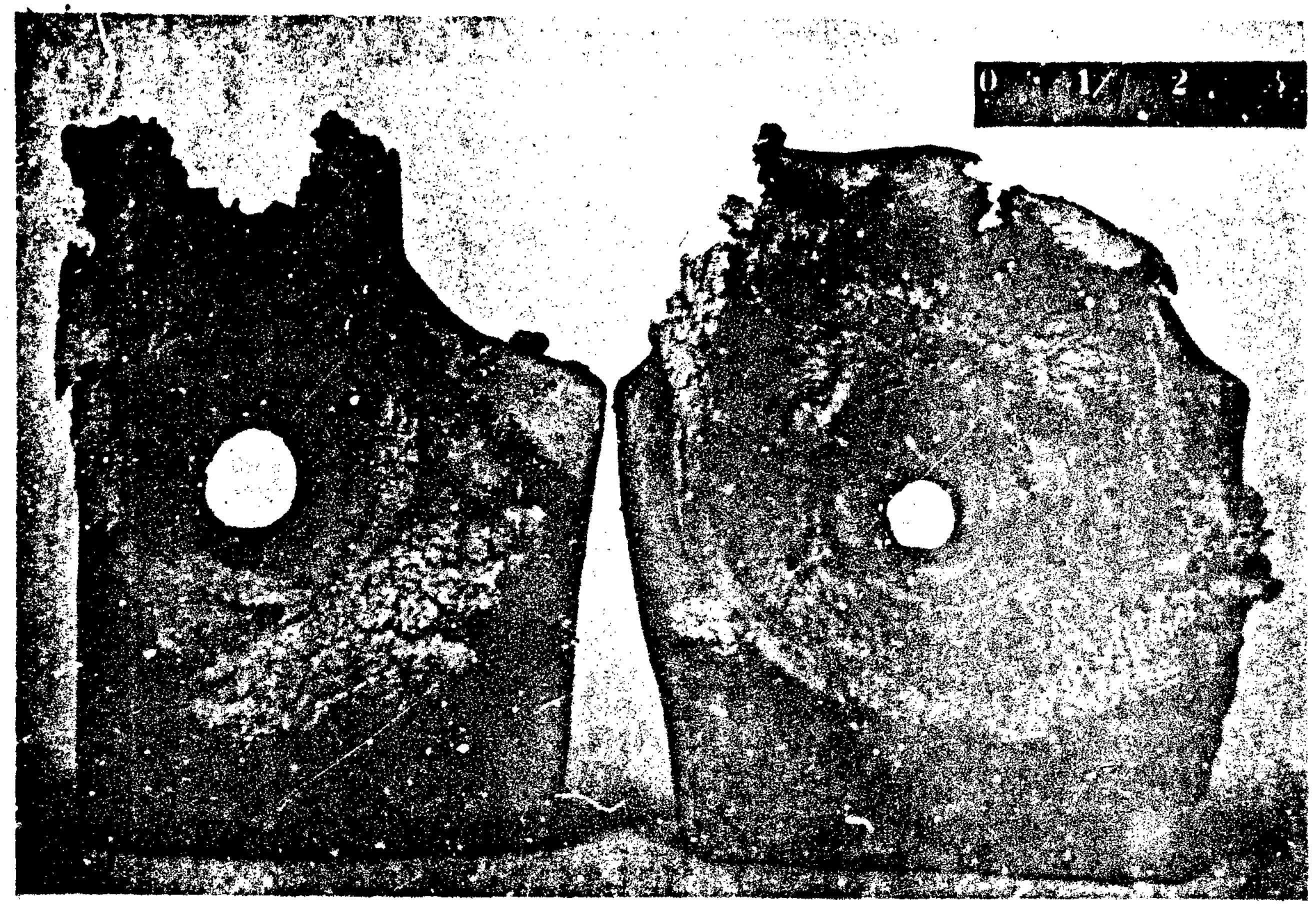


FIG. 20A (Exit). Infantry Rifle Study.
LEFT: Caliber .30 Ball, M2. Velocity: 2380 f/s
RIGHT: Caliber .22. Velocity: 2770 f/s

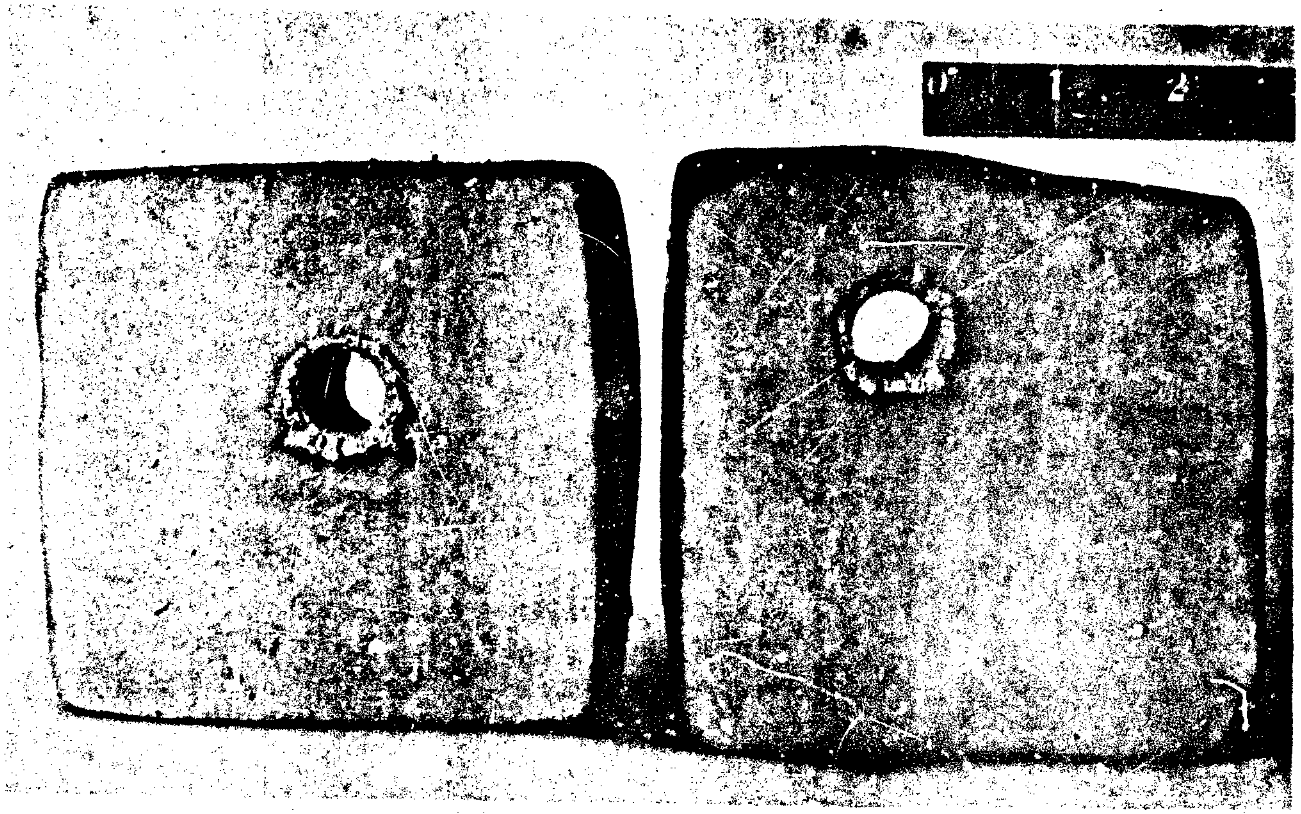


FIG. 21 (Entrance). Infantry Rifle Study.
LEFT: Caliber .30 Ball, M2. Velocity: 1900 f/s
RIGHT: Caliber .22, Velocity: 2180 f/s

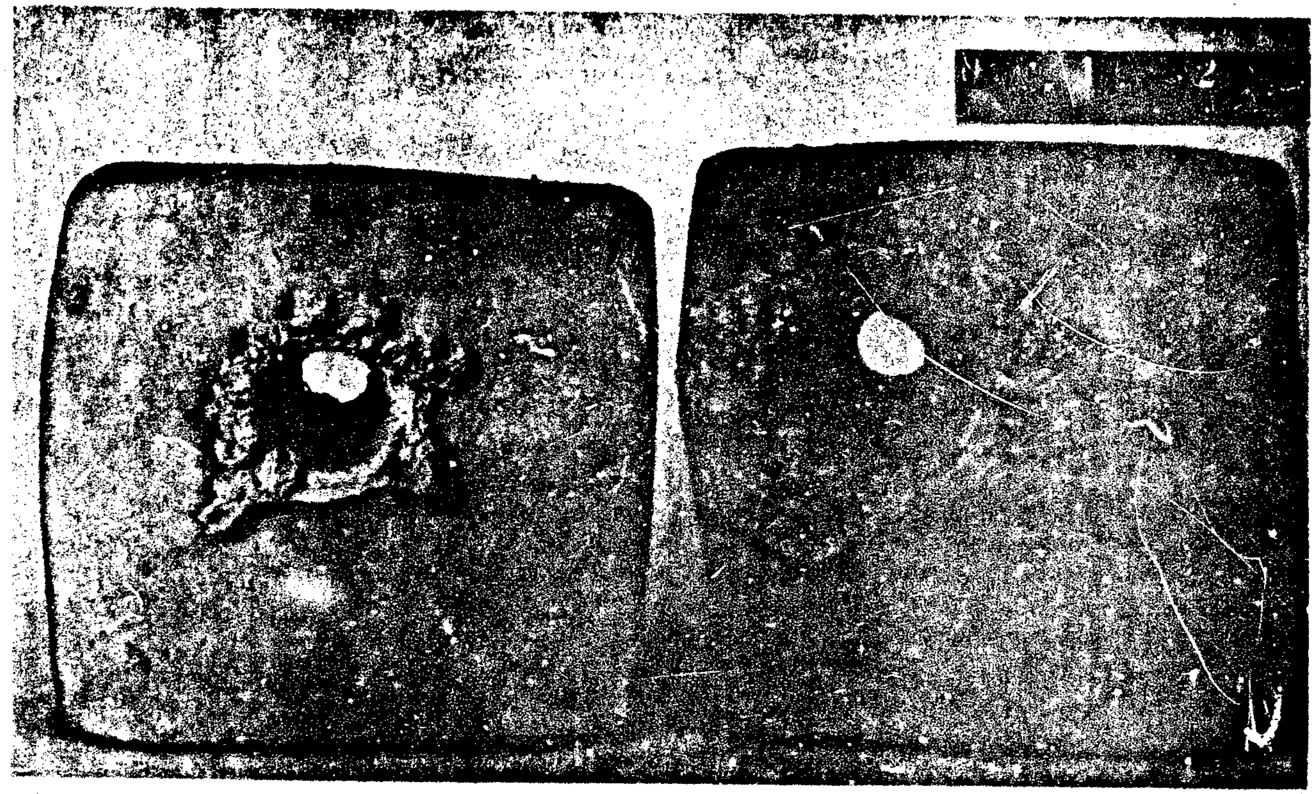


FIG. 21A (Exit). Infantry Rifle Study.
LEFT: Caliber .30 Ball, M2. Velocity: 1900 f/s
RIGHT: Caliber .22. Velocity: 3180 f/s

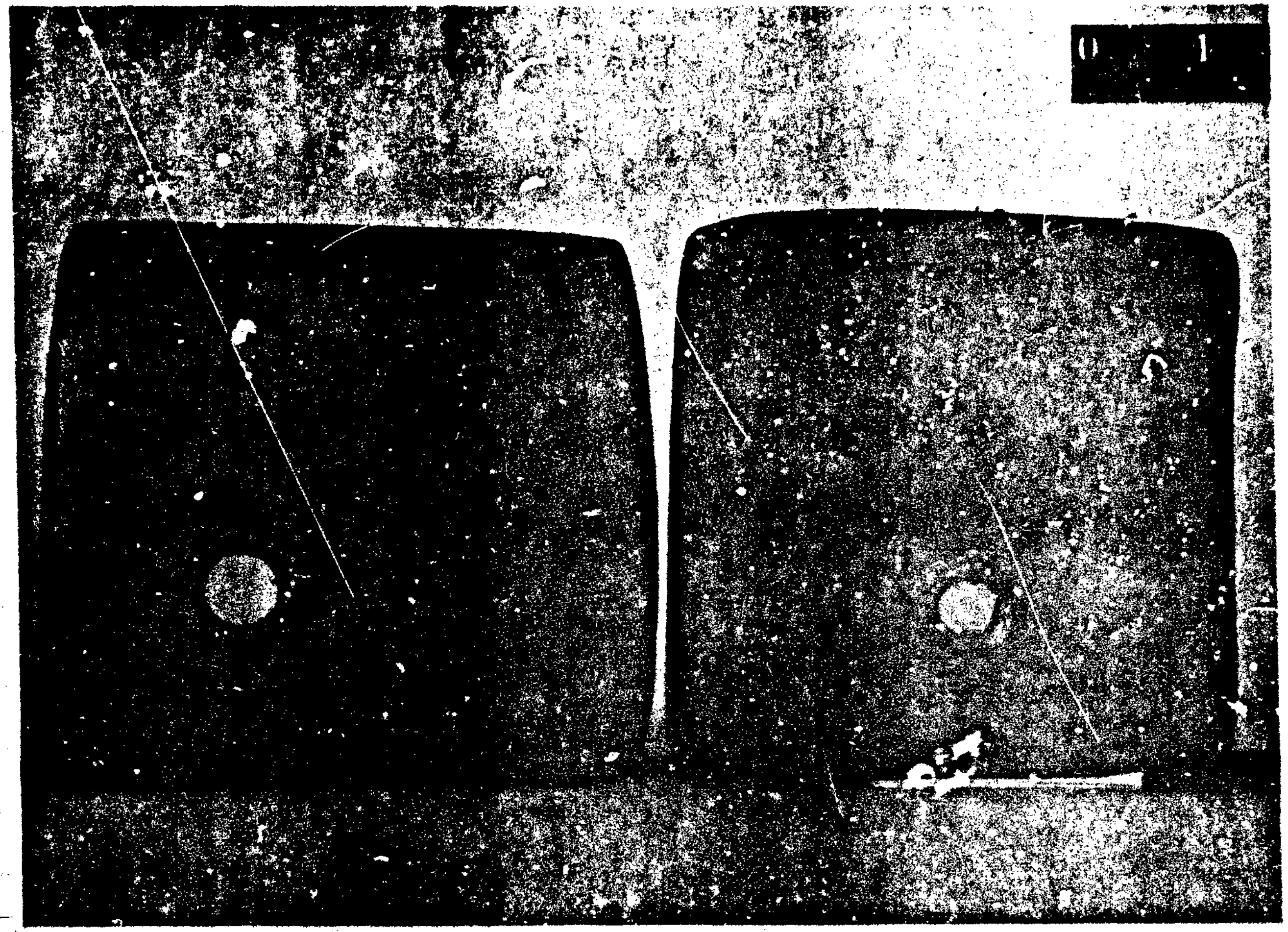


FIG. 22 (Entrance). Infantry Rifle Study.
LEFT: Caliber .30 Ball, M2. Velocity: 1565 f/s
RIGHT: Caliber .22. Velocity: 1616 f/s

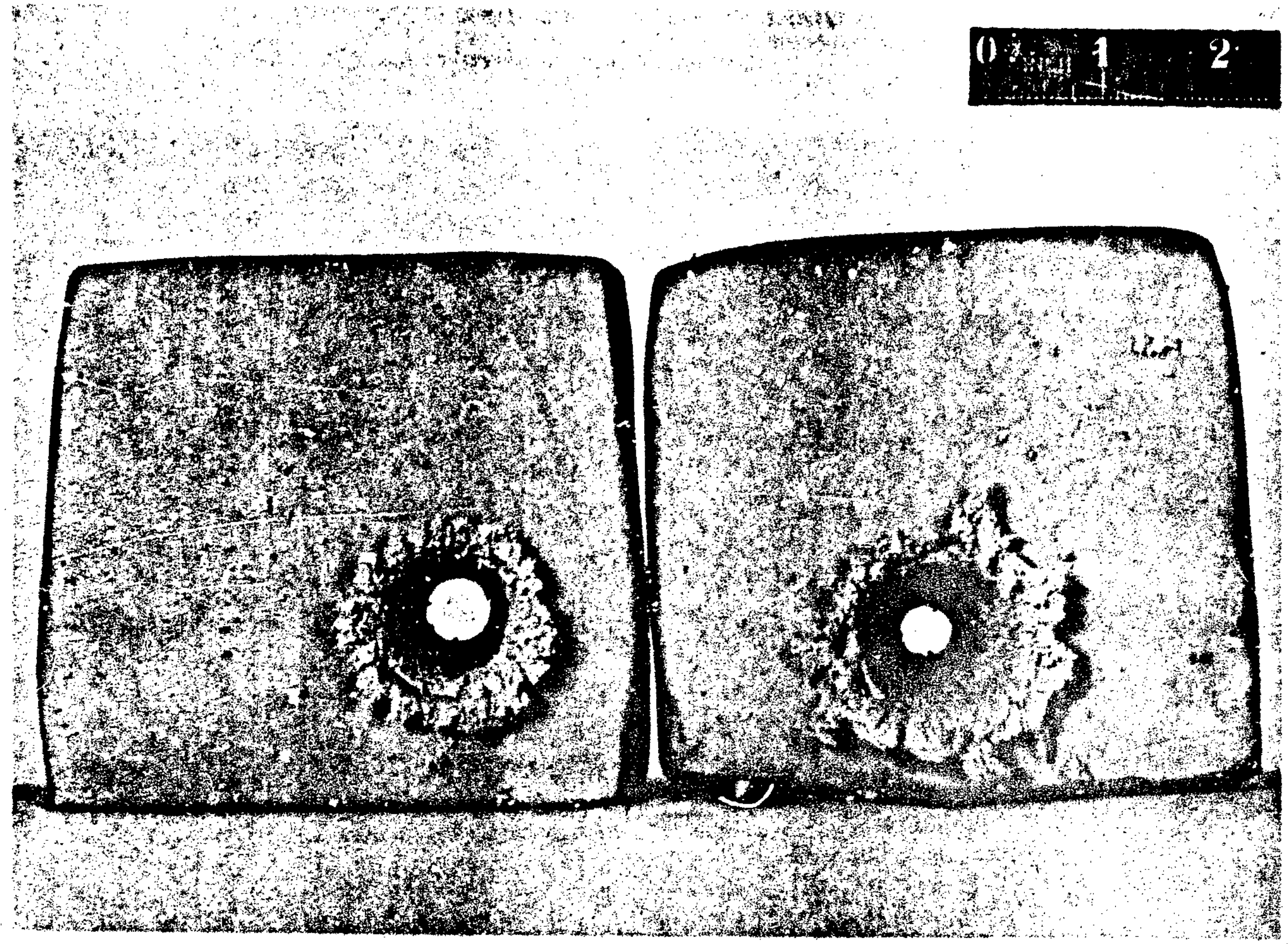


FIG. 22A (Exit). Infantry Rifle Study.
LEFT: Caliber .30 Ball, M2. Velocity: 1865 f/s
RIGHT: Caliber .22. Velocity: 1610 f/s

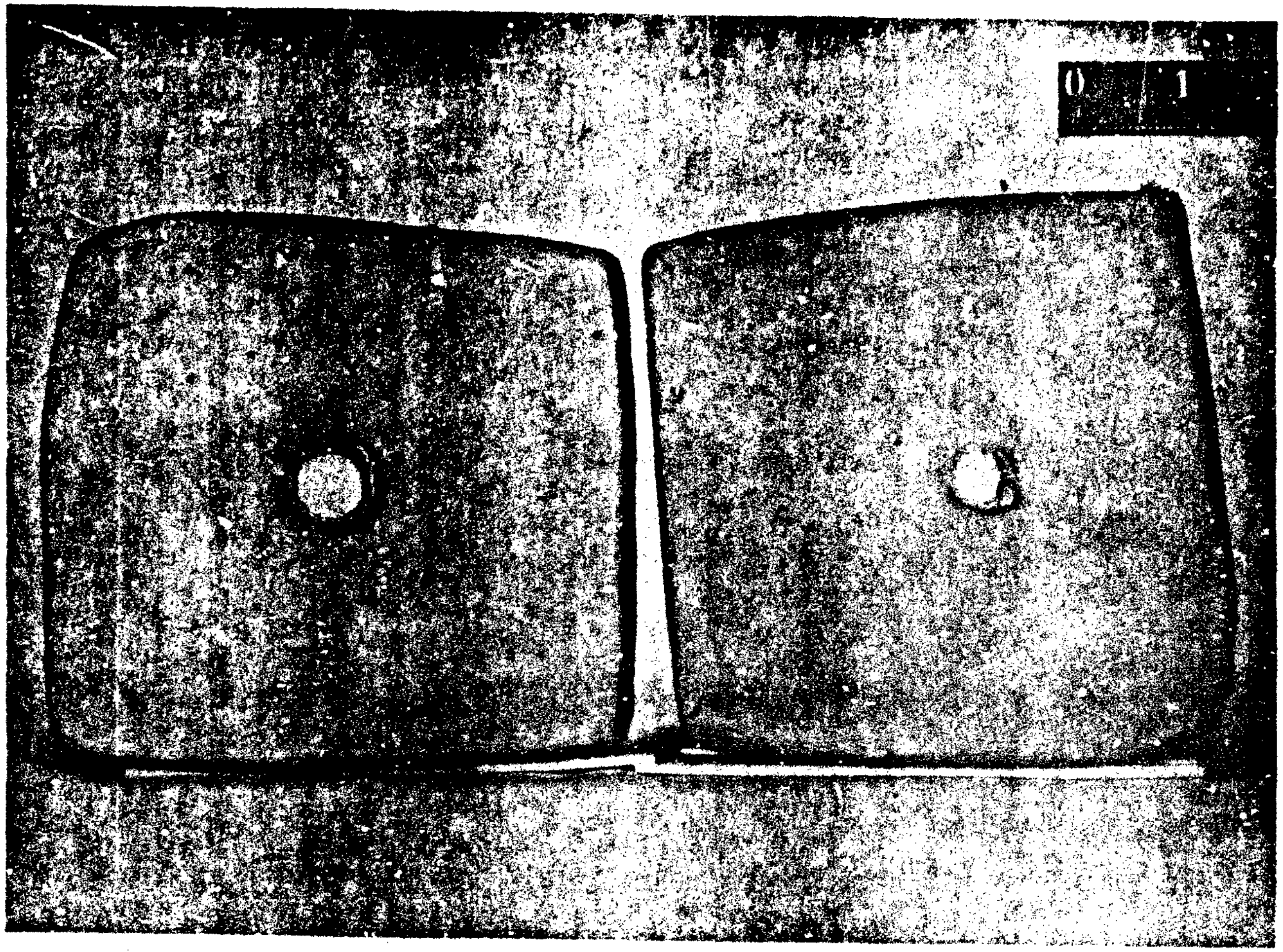


FIG. 23 (Entrance). Infantry Rifle Study.
LEFT: Caliber .30 Ball M2. Velocity: 1250 f/s
RIGHT: Caliber .22. Velocity: 1280 f/s

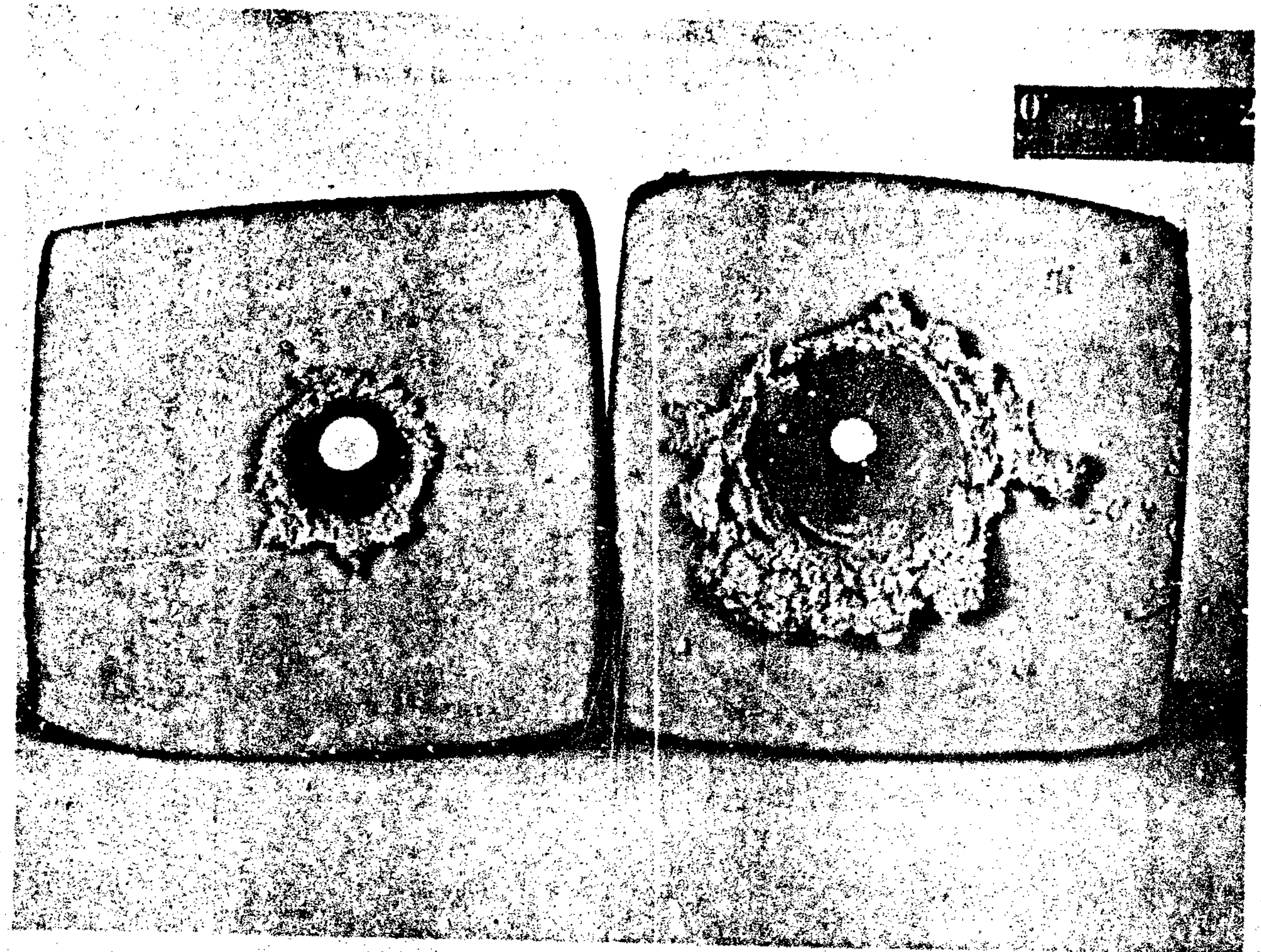


FIG. 22A (Exit). Infantry Rifle Study.
LEFT: Caliber .30 Ball M2. Velocity: 1380 f/s
RIGHT: Caliber .22. Velocity: 1380 f/s

FIG. 24

CAVITY SIZE VS. RANGE